JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA,
FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXIII. APRIL, 1887. No. 4.

THE FRANKLIN INSTITUTE is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

THE SELLERS OR FRANKLIN INSTITUTE SYSTEM OF SCREW-THREADS.

The following correspondence has grown out of an inquiry addressed to the INSTITUTE by the Society of German Engineers of Berlin, and is self-explanatory. W. H. W.

BERLIN, W., den 22. October, 1886,
Wichmannstrasse 14.

An das FRANKLIN INSTITUTE, *Philadelphia (V. St. A.), 15 South Seventh Street.*

Für die in unserm Vereine noch immer im Gange befindliche Agitation zur Aufstellung eines einheitlichen Schraubengewindesystems auf Grundlage des Metermaasses, würde es uns von hohem Werthe sein, die Verhandlungen und Beschlüsse eines verehrlichen FRANKLIN INSTITUTE über diese Frage kennen zu lernen; insbesondere würde es uns interessiren, zu erfahren, ob in den Ver. Staaten ein Standard-Gewinde aufgestellt ist, und zwar welches, und welche Geltung es bisher erlangt hat.

In der Zeitschrift *Engineering*, vom 10. September d. J., ist ein Aufsatz, welcher unter Anderem die Behauptung enthält, dass das von Sellers vorgeschlagene Gewinde, mit geraden Flächen statt der Whitworth'schen Abrundungen, als nicht bewährt befunden und wieder aufgegeben worden sei; auch hierüber wären uns Mittheilungen sehr erwünscht.

Mit Freuden bereit, auch Ihnen vorkommenden Falles zu Diensten zu sein, zeichnen wir Hochachtungsvoll,

DER VEREIN DEUTSCHER INGENIEURE.
Th. Peters.

[*Translation.*]

BERLIN, W., October 22, 1886.

To the FRANKLIN INSTITUTE, *Philadelphia* (*U. S. A.*), *15 South Seventh Street.*

In connection with the subject of establishing a uniform system of screw-threads based on the metrical system—which, for a long time, has been agitated by this society—it would be of the greatest value to us to be advised respecting any proceedings taken and conclusions reached by the FRANKLIN INSTITUTE upon this subject. It would especially interest us to learn if any standard has been adopted in the United States, and if so, what standard, and to what extent it has, up to the present time, received acceptance.

In *Engineering*, of September 10, 1886, there appears an article on this subject, in which the assertion is made, that the system of threads, proposed by Sellers—having straight surfaces instead of the rounded ones of Whitworth—had not been found to fully meet the requirements of practice, and had been abandoned. On this point, also, any information would be very acceptable. With the expression of our willingness to serve you, should the occasion offer itself, we subscribe ourselves,

With high regard,

THE SOCIETY OF GERMAN ENGINEERS,

Th. Peters.

The article in (London) *Engineering*, herein referred to, is given below, viz.:

In the year 1857, many of the leading engineers in England began to recognize the evil and the very great inconvenience which arose from various quarters through individual machine and engine makers using a separate system of screw-threads. So important did Sir Joseph Whitworth consider the matter, that he undertook to establish and introduce a uniform system of standard pitches and form of thread for use throughout the country. His first table was published in the same year, viz., 1857, and a second one in 1861, in which he gave fuller particulars, and proposed a few minor improvements. The main points to be considered in arranging such a system were, briefly:

(1.) The best and most suitable pitches or number of threads per inch of length for given diameters of bolts, the main object being to reduce the strength of the bolt as little as possible, and at the same time to make the threads of sufficient depth to prevent liability to "cross-threading" taking place, and to get a convenient thickness of nut which would stand at least as much longitudinal tensile stress as the bolt at the bottom of the thread. After very careful consideration on the part of Sir Joseph Whitworth, he decided upon a set of pitches, which were published in tabular form, copies of which are found in all engineering text-books. The following formula, taken from Unwin's *Machine Design*, page 117, gives a very close approximation:

Let d = the original diameter of the bolt.

p = the pitch of the threads.

Then

$$p = 0{\cdot}08\,d + 0{\cdot}04,$$

and the diameter at the bottom of the thread,

$$d' = 0{\cdot}9d - 0{\cdot}05.$$

(2.) The form or cross-section of the thread best suited for practical purposes, which involved the consideration of ease of manufacture and reproduction, combined with security against damage by the comparatively rough treatment bolts and screws are subjected to. The form of cross section Whitworth adopted for ordinary purposes was that of a triangle, whose height was 0·96 pitch and the angle at the bottom of the threads 55° (see Unwin's *Machine Design*, page 117); one-sixth of these triangular sections was rounded off at the top and bottom. This system has been very widely and almost universally used for the last thirty years, the chief and only important exception to their universality being in the United States, where Sellers's threads are very much used; they are of a slightly different pitch, and form of cross-section, being an equilateral triangle with one-eighth of the depth cut off square, both top and bottom; the pitch is nearly $p = 0{\cdot}1\,d + 0{\cdot}025$, and the diameter at the bottom of thread $d_1 = 0{\cdot}87\,d - 0{\cdot}03$. (See Unwin's *Machine Design*, page 119).

The relative values of these two systems lie chiefly in the merits of round or sharp corners. We shall return presently to consider both systems in detail, but it is well to note here that the latter system is being discarded for one very similar to the Whitworth. This is briefly how the screw-thread question stands at the present time. However, in Germany and on the Continent of Europe generally, the English system of measurement in feet and inches is not in common use, but the metrical system is almost universal, viz., of meters with decimal subdivisions. Hence, a small body of German engineers have been for some time urging for a universal metrical standard of screw-threads, and consequently seek to overthrow the Whitworth system.

In 1874,* the München District Society of German Engineers, took up the matter, when they not only procured the opinions of the German district societies, but communicated with various well known Continental engineering societies, and at the same time sent out 2,000 circulars to owners of works to obtain their views upon the practicability of introducing a metrical system in the place of Whitworth's, maintaining that this system was not in general use; but the result of this inquiry was in favor of retaining the Whitworth system.

Out of the 2,000 circulars sent out, only 365 were returned, 316 of which were from makers who used the Whitworth system exclusively, and the remaining forty-nine retained the pitch, but used different diameters of bolts. Of the twenty district societies which were consulted, only six decided in favor of the metrical system. The practical effect of this inquiry was to set the Whitworth system on a firmer basis than ever. In spite of this, however, the Karlsruhe District Society brought forward motions in favor of the metrical system at the principal meeting of the Society of German Engineers in 1877, but they were at once dismissed by them. Again, in 1885, the same society brought up the matter under a rather a different aspect, viz., not whether it was

* *Vide* a paper "On the Thread Question," by J. H. Mehrtens, engineer, of Berlin

desirous to introduce a metrical system of screw-threads, but what metrical system shall be introduced, implying that the former was a settled matter, and the only matter requiring consideration was the details of the system.

The directorate thought it desirable to appoint a special commission to inquire into it. The main objections brought against the Whitworth system by the commission and the Karlsruhe Society, were briefly:

(1.) The Whitworth system is not universally used in Germany, and consequently great disorder prevails.

(2.) The Whitworth system being measured in inches, it is inconvenient for metrical measurements.

(3.) The cross-section of the Whitworth thread is difficult of manufacture.

The first objection has been dealt with above in the remarks on the action taken by the Karlsruhe and München District Societies, and, again, the Whitworth system is universally used by the German railways and dockyards, and unless a general desire is shown for a metrical system of threads, it is evidently quite useless for a handful of obscure scientific men to attempt a radical change in such an important matter.

The second objection, on the surface, appears slightly more justifiable, but even that is extremely insignificant when more closely examined and viewed from a different standpoint. This matter does not stand upon the same ground that it did ten years ago, when the whole of the bolts and screws in use were constructed in small quantities as they were required at the various machine and engine works; to-day, the case is totally different, as only a very small percentage are constructed in this way; they are almost entirely bought from special screw-makers, who turn out better and cheaper work than is possible for individual machine shops. Thus, the imaginary difficulty lies entirely in the screw-makers' hands. They do not complain; why, then, should those whom it does not affect to any appreciable extent?

If a new universal system of screw-threads must be adopted, then it should not be tied down to any special system of measurement, but should rather be designed on a system of standard gauges of various grades, similar to our Birmingham wire-gauge system. Some of the German engineers complain that a considerable number of Whitworth bolts and nuts purchased from one firm of screw-makers, will not fit those purchased from another firm, and lay the blame to the system, but this is decidedly unjust, for it is evident to any practical engineer that the fault lies not in the system itself, but with the manufacturers for not using standard screw-gauges as Sir Joseph Whitworth advocated in his original report on the subject. None can say but what the proposed new system would be quite as faulty, perhaps even worse in this respect, as it has never been practically put to the test. If German engineers persist in their course and carry out this proposed scheme in the machinery they manufacture, they only will be the sufferers by ruining their foreign trade, for no foreigners will think of purchasing machinery which cannot readily be repaired by local engineers without sending to Germany for special bolts and nuts.

The third objection is totally unjustifiable, for thirty years of practice have most unmistakably proved the Whitworth form of cross-section to be

the best; the square-tipped thread, on the other hand, as advocated by the metrical system, has proved unsuccessful; it has been thoroughly tried by Sellers in the United States, where it has been found practically impossible to produce a good thread by screwing-apparatus; the sharp corners on the taps and dies rapidly break away, when a very imperfect thread must naturally follow. The present state of affairs in America conclusively shows the system to have been a failure, and all the leading machine-tool makers there are supplying nothing but the V-thread, very similar to Whitworth's.

Again, the strength of the bolt is reduced more by the square-cornered than by the rounded thread, although the sectional areas of the bolts at the bottom of the threads are the same; for example, it is always found to be absolutely necessary in the preparation of test specimens for tensile tests to have the corners well rounded off; if not, the specimen almost invariably breaks short off at the square corner. With good tools and good men to use them, there is no difficulty whatever in producing the Whitworth cross-section of thread. The round at the bottom of the thread is easily produced by a rounded point to the screw-cutting tool, a gauge for which is carried by every turner in his waistcoat pocket. The round at the top of the thread is produced by the chaser, which is itself cut by a standard hob, and consequently reproduces the correct form of cross-section on whatever work it is used.—*Engineering, Sept. 10, 1886.*

SECRETARY'S OFFICE, HALL OF THE FRANKLIN INSTITUTE.
PHILADELPHIA, January 31, 1887.

The Society of German Engineers:

GENTLEMEN:—In response to your letter of October 22d ult., asking to be informed respecting any proceedings taken and conclusions reached by this INSTITUTE, upon the subject of establishing a uniform system of screw-threads, whether any standard has been adopted in the United States, and if so, what standard, and to what extent it has, up to the present time, received acceptance, also referring to an article in *Engineering*, of September 10, 1886, with quotation therefrom, I have the honor to report:

The proceedings taken by the FRANKLIN INSTITUTE, with reference to a uniform system of screw-threads, were inaugurated by a paper upon this subject, by Mr. Wm. Sellers, read by him before the INSTITUTE at its regular monthly meeting, held April 21, 1864, (see copy of the JOURNAL for April of that year, forwarded, with other papers hereinafter referred to, by book-post on the 31st inst.) This was followed by the appointment of a committee to investigate and report. The report of this committee will be found in the number of the JOURNAL for January, 1865, forwarded as above, and this ended the proceedings so far as the FRANKLIN

INSTITUTE was concerned. Early in 1868, the Secretary of the Navy of the U. S., appointed a Board of Engineers, to investigate and report upon a system of screw-threads, which might with advantage be adopted by that department of the Government, and this Board reported May 9, 1868, recommending the system advocated by Sellers, and approved by this INSTITUTE (see copy of report forwarded as above). This report was approved by the Secretary of the Navy, and thenceforth it has been the standard for the U. S. Government, not only for the Navy Department, but for all other departments, excepting for small arms and other specific requirements, where a much finer thread is necessitated. This action by the Government was followed by its general adoption in the large private establishments all over the country engaged in constructing the heavier classes of machinery.

In April, 1869, the Pennsylvania Railroad Company ordered a set of gauges to the new form of thread, and adopted the system upon all of its lines, and this was followed by various other railroads throughout the country, until in 1872, the Master Car Builders' Association recommended the Sellers or FRANKLIN INSTITUTE System of Screw-Threads and Bolts as a standard. The progress thereafter in this direction is shown by the *Report of the Proceedings for 1885*, forwarded as above, and similar action was taken by the Master Mechanics' Association.

To answer your inquiry, "to what extent it has, up to the present time, received acceptance," and also "the article in *Engineering*" before referred to, the Secretary of the INSTITUTE addressed the following letter to the proper officers of the principal railroads in the United States, and to several individual manufacturers:

PHILADELPHIA, December, 1886.

To the Superintendent of ———— *Railroad Company:*

DEAR SIR:—The Society of German Engineers of Berlin has made certain inquiries of the FRANKLIN INSTITUTE, concerning the Standard Screw-Thread recommended for general adoption by the FRANKLIN INSTITUTE in 1864, and adopted by the Navy Department of the United States in 1868, among which inquiries the durability of the straight surfaces as compared with the rounded ones of Whitworth, is questioned. It is probable that the straight surfaces of the standard thread would show a modification of form to the eye which would not be observable upon the curved surface of the Whitworth thread; but, as some contribution to this inquiry, it would be of interest to know whether the standard thread has been adopted upon your road, and whether you have experienced any difficulty in practically maintaining the

form of the thread, or at least sufficiently so as to make the nuts interchangeable. If you find that the straight surfaces are more difficult to maintain than the curved ones of the Whitworth thread, would this be counterbalanced by the greater facility for making the straight thread with a single tool over that of the curved thread which requires two (2) tools, and which form of thread can most easily be constructed and tested, for accurate conformity with a standard of its form? Any information you can give me in connection with this subject will be highly appreciated by, Yours truly,

WM. H. WAHL, *Secretary.*

IN RESPONSE to this letter, he has received replies from the following railroad companies:

Pennsylvania Railroad Company, operating and controlling 7,346 miles of railroad.

Chicago, Milwaukee and St. Paul Railway Co., 4,921 miles.

New York Central and Hudson River Railroad Co., 993 miles.

Chicago, Rock Island and Pacific Railroad Co., 1,383 miles.

Delaware, Lackawanna and Western Railroad Co., 889 miles.

Louisville and Nashville Railroad Co, 3,727 miles.

Chicago, Burlington and Qu ncy Railroad Co., 3,646 miles.

New York, Lake Erie and Western Railway Co, 1,601 miles.

He has also a reply from one of our largest manufacturers of bolts and nuts, and one from our most important manufacturers of taps and dies. The article in the *Railroad Gazette*, of September 24, 1886, referred to by the latter, is forwarded by book-post with the other paper hereinbefore referred to.

THE LETTERS received in response to the Secretary's inquiry are as follows:

Louisville and Nashville Railroad Company. Harvey Middleton, Superintendent Machinery.

LOUISVILLE, Ky., December 6, 1886.

WILLIAM H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—Yours of December 14th is at hand and noted. We adopted the United States Standard thread, sometimes called the FRANKLIN INSTITUTE Thread, about five (5) years ago, in all the shops of our lines, and have used it ever since. We have found no difficulty whatever from the wearing of the taps and dies as long as they are not used beyond a proper length of time. Of course, as taps and dies wear away, it will make a slight difference in the form of the thread; but, I do not believe that that change is any greater or can give any more trouble than in the case of the Whitworth thread referred to. We have experienced no difficulty in the interchange of nuts and bolts on account of the slight change that occurs in the form of the thread in the wearing of the taps and dies. Of course, any form of thread will change slightly from the wearing of the taps and dies, and it is impossible to avoid

that by any form of thread used. A straight side to a thread is easier to make than a rounding side, and therefore more likely to be perfect. A straight side to a thread, it seems to me, will change as little, perhaps less, than a rounding side. The proper way to keep threads as near the original as possible is to throw away the taps and dies before they are worn to such an extent as will make any practical difference in the shape of the thread. This is a matter that is sometimes overlooked. The expense of taps and dies is not great, and only perfect taps and dies should be used; and as soon as the wear amounts to enough to make an appreciable difference in the form of the thread, they should be thrown away and renewed. We have made it a rule to purchase from reliable manufacturers nearly all of our taps and hobs for cutting dies, and we have been particular to throw away taps as soon as they are worn to any considerable extent, and use new ones. The same in regard to dies; as soon as the wear amounts to anything, we re-cut them, dress them up and then they are as good as new. It seems to me a flat-top form of thread will change as little as a thread that runs to a point. It will change less in diameter from out to out of the thread. With a sharp-top thread, when the sides wear away slightly, it reduces the height of the thread. With a flat-top thread the wear of the sides will not reduce the diameter from out to out of the thread, but will simply make the thread a little thinner at the point, etc.

Yours truly,

R. WELLS, *Superintendent Machinery.*

Delaware, Lackawanna and Western Railroad Company. Office of Machine Shops.

SCRANTON, Pa., December 8, 1886.

MR. WM. H. WAHL, Secretary of the FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—Replying to yours of the 4th inst., in regard to the Standard Screw-Thread, would say, the United States Standard has been adopted on this road and gives entire satisfaction. It is much easier to make, and the tools to make it less expensive to keep up.

Yours truly, CHAS. GRAHAM, *Master Mechanic.*

Chicago, Milwaukee and St. Paul Railway. Office of General Master Mechanic.

WEST MILWAUKEE, Wis., December 11, 1886.

WM. H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE of Pennsylvania, Philadelphia, Pa.

DEAR SIR:—I make the object of this, to reply to your favors of the 4th inst. In 1871, the locomotive department of this company adopted what is known as the United States, or FRANKLIN INSTITUTE Standard, for Diameters and Threads, and have continued to use it up to the present time. We have experienced no particular difficulty in the interchanging of nuts. Should there be any difficulty in maintaining the straight surfaces of the threads more than those of the Whitworth type, it would in our opinion be more than counterbalanced in costing less to maintain the straight surfaces than the

curved. We are of opinion, however, that the Whitworth thread is the strongest, *i. e.*, less liable to fracture the bolt.

I am, yours truly, I. M. LOWRY, *General Master Mechanic.*

Chicago, Rock Island and Pacific Railroad. Master Mechanic's Office.

CHICAGO, December 15, 1886.

WM. H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—About three years ago we adopted the United States Standard Thread for Bolts and Nuts, and have so far experienced no difficulty whatever in practically maintaining the form of the thread. I have not yet seen a case where a bolt had worn so that nuts were not interchangeable.

I have had very little experience with the Whitworth thread, but feel certain that any slight advantage in durability or strength which it may have over the United States Standard, is far outweighed by the inconvenience in its construction. Regretting that I cannot give you more scientific and interesting data, I am, Yours truly,

THOS. B. TWOMBLY, *General Master Mechanic.*

Chicago, Burlington and Quincy Railroad Company. Office Superintendent Motive-Power.

AURORA, Ill., January 5, 1887.

FRANKLIN INSTITUTE of Pennsylvania, WM. H. WAHL, Secretary, Philadelphia, Pa.

DEAR SIR:—Yours of the 4th duly received, asking whether this road has adopted the United States Standard thread, and whether we have experienced any difficulty in maintaining the form of the thread.

The United States Standard or FRANKLIN INSTITUTE Thread was adopted in the car department of the Chicago, Burlington and Quincy, in 1883, and since then has been gradually introduced into the locomotive and track departments. For two years past we have used this thread for all purposes. We have had no difficulty whatever in maintaining the form of the thread, that is to say, we can forward to any point on our line new nuts, which can be used satisfactorily on old bolts. Our foremen all speak highly of the United States Standard, owing to the facility of maintaining a uniform shape.

One of our foremen at Burlington, Mr. Scholey, who has used the Whitworth thread in the old country, and the United States Standard in this country, says the latter is much more easily maintained.

We enclose you some correspondence from our master mechanics on this matter.

(A.) J. West, M. M., Burlington shop.

(B.) L. E. Johnson, M. M., Aurora.

(C.) C. F. Geyer, General Foreman Aurora Shop.

Yours truly, G. W. RHODES, *Supt. M. P.*

A.

Chicago, Burlington and Quincy Railroad Company. Locomotive and Car Department.

WEST BURLINGTON, December 16, 1886.

G. W. RHODES, ESQ., Superintendent Motive-Power.

DEAR SIR: Referring to attached letters in regard to screw-threads, I fully agree with Messrs. Johnson and Geyer in the matter of threads.

I have talked this matter over with our general foreman, Mr. Scholey, and he says that with our American or United States Standard, it is much easier to keep up taps and dies than with the Whitworth thread with rounded edges and angles, which he used in the old country, and a good fit is easier to make.

Yours, J. A. WEST.

Nuts.—United States Standard *vs.* Whitworth Thread.

B.

Chicago, Burlington and Quincy Railroad Company. Master Mechanic's Office.

AURORA, Ill., December 11, 1886.

G. W. RHODES, ESQ., Superintendent M. P., Aurora.

DEAR SIR:—Returning your communication from the FRANKLIN INSTITUTE, and, in reply to the same, would respectfully state that the United States Standard thread has been in use in the car department since 1883. During that time, we have experienced no difficulty whatever in practically maintaining the form of the thread; that is to say, that we can forward to any point a supply of new nuts, which can be used on bolts that have been in service since that time.

Foremen of other shops substantiate Mr. Geyer's statement, that it is much more difficult to maintain the curved surface of the Whitworth thread than the straight, or United States Standard. We have no absolute data on this subject, other than practical experience for the past three years. We are gradually changing the thread of bolts in all departments to the straight, or United States Standard. In doing this, we experience no difficulty or annoyance, as the men in each department keep a small quantity of old nuts with the old thread, so as to avoid throwing away bolts.

We undoubtedly shall eventually have nothing but the United States Standard thread in use in all departments.

I enclose you copy of Mr. Geyer's report.

Yours respectfully, L. E. JOHNSON.

C.

AURORA, Ill., December 9, 1886.

L. E. JOHNSON, ESQ, Div. M. M., Aurora.

DEAR SIR:—In regard to the enclosed, it is my opinion that the Whitworth Standard tap is very impracticable, as it is a hard matter to make them twice alike, therefore, much more expensive. It is true, if a nut and bolt is in constant use, it will wear about the shape of the Whitworth Standard, and it may be more durable. We have never, as yet, experienced any

trouble with the United States Standard thread. A new nut can always be substituted where an old one of the same size is taken off.

It will cost at least double to maintain the tools of the round or Whitworth thread, and, it is my opinion, it is not any better or stronger than the straight or United States Standard thread.

Respectfully yours, [Sgd.] C. F. GEYER.

SUBJECT—STANDARD SCREW-THREADS.

The Pennsylvania Railroad Company. Office of General-Superintendent of Motive-Power.

ALTOONA, Pa., December 20, 1886.

WILLIAM H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—In reply to your letter of December 3d, would say, that in our experience we have had no trouble at all in maintaining the form of thread of the United States Standard, and the nuts we tap are perfectly interchangeable.

We think, the straight surfaces are much more easily maintained than the curved ones of the Whitworth thread would be, for the reason that it is easier to discover irregularities in straight than in curved lines, and it is quite easy to grind a thread cutting-tool to the straight lines of the standard thread.

Yours truly,

THEO. N. ELY, *General-Superintendent Motive-Power.*

The New York Central and Hudson River Railroad Company. Office Superintendent Motive-Power and Rolling Stock. Room 14, Grand Central Station.

WM. BUCHANAN, *Superintendent.*

NEW YORK, December 20, 1886.

WM. H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—In answer to your inquiry of 4th inst., we adopted the United States Standard form of thread three (3) years ago, and have never experienced any difficulty in maintaining the form of the threads, or in making nuts interchangeable.

For durability, think the Whitworth thread is the best, but for ordinary work, think this feature is offset by the difficulty in reproducing it.

The facility with which the straight threads can be produced by an ordinary workman with tools that can be readily made and maintained, so as to conform to the standard gauges, is a recommendation sufficient in itself.

Yours truly, WM. BUCHANAN.

New York, Lake Erie and Western Railroad Company. Office Superintendent of Motive-Power.

BUFFALO, N. Y., February 8, 1887.

WILLIAM H. WAHL, ESQ., Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—In answer to yours of December 4th ult., making inquiry in regard to the Standard Screw-Thread recommended for general adoption by FRANKLIN INSTITUTE in 1864, in comparison with the Whitworth thread, would say that we have made careful inquiry in regard to this matter from all

our master mechanics and foremen of car-repair, and the general opinion is about as follows:

There is little question about the practical superiority of the Sellers, or United States Standard thread.

The principal differences between the two are in the angle of the thread and the form at top and root of thread.

The angle of the Sellers thread is more easily maintained than the other, because a templet can be accurately made without the use of special tools, as it is easy to construct the angle geometrically. It is also simpler and cheaper to cut the Sellers thread in a lathe. It is a difficult matter to make the nut fit closely on the curved portion of the Whitworth thread, and practically the bearing surface will probably be limited to the straight parts making it considerably less than in the Sellers system, consequently more liable to be distorted as far as this element goes.

We have no trouble arising from the wear of the United States Standard tap sufficient to prevent the nuts from being interchangeable.

Yours truly,

ROBERT SOULE, *Superintendent Motive-Power.* T.

The Pratt & Whitney Company, Manufacturers of Machinists' Tools.

HARTFORD, Conn., U. S. A., December 29, 1886.

DR. WM. H. WAHL, Secretary FRANKLIN INSTITUTE, Philadelphia, Pa.

DEAR SIR:—Your favor of the 28th inst., is to-day received. We trust you will pardon us for the delay in complying with your esteemed request of the 4th inst., mainly due to absence of the writer to whom the matter was referred, and subsequent unusual demands upon his time.

Regarding our experience as manufacturers of taps and dies, especially those covering the application of the Sellers System of Screw-Threads, now known as the FRANKLIN INSTITUTE or United States Standard, we can say, as stated in our letter in the *Railroad Gazette*, and published in their issue of September 24, 1886, included in article on "Screw-Threads," the orders we have received for taps and dies from railroad companies, bolt manufacturers, bridge builders and manufacturers generally, in the United States, are largely for the United States Standard thread. Fully ninety per cent. are strictly so, and many of the others not United States Standard in form of thread and pitch, are so in shape of the thread, *i. e.*, flat at top and bottom, one-eighth of the pitch, and having a greater number of threads per inch.

This is necessary for special cases, such as tool work and small diameter taps and bolts.

The form of the Sellers, FRANKLIN INSTITUTE or United States Standard thread, is such as to make it the most practicable for duplication to gauge, and by making the outside diameter slightly larger (not, however larger in the angle of the thread), the life of the tap or before it wears below gauge size, is greatly lengthened.

The claim that the form of the Sellers thread cannot be maintained in use, seems in our experience, inadmissible, for although the corners may wear slightly, this wear is unimportant if the taps are properly used, and

especially so, if made as recommended—slightly larger in the outside diameter.

Our position in the matter is stated more fully in the article published in the *Railroad Gazette*, referred to, and should you desire further information, or other than here given, we shall be only too glad to be of service to you if in our power.

May we retain the copies of the translation and the letter issued to the railway companies?

Regretting the delay, we are, Yours respectfully,

THE PRATT & WHITNEY COMPANY,

GEO. M. BOND, *Manager Gauge Department.*

[Following is the article from the *Railroad Gazette, September 24, 1886*, referred to in Mr. Bond's letter.]

SCREW-THREADS.

The last issue of *Engineering* publishes an article on "Screw-Threads," chiefly dealing with a movement, in Germany, to abandon the Whitworth Standard for a new one based on metric measures, in which some very large-sized and strangely erroneous statements are made in reference to what has now become the American Standard—the Sellers thread. It says:

"The form of cross-section Whitworth adopted for ordinary purposes, was that of a triangle, whose height was 0·96 pitch and the angle at the bottom of the threads 55°; one-sixth of these triangular sections was rounded off at the top and bottom. This system has been very widely and almost universally used for the last thirty years, the chief and only important exception to their universality being in the United States, where Sellers threads are very much used: they are of a slightly different pitch and form of cross-section, being an equilateral triangle with one-eighth of the depth cut off square, both top and bottom.

"The objection (to the form of the Whitworth thread) is totally unjustifiable, for thirty years of practice have most unmistakably proved the Whitworth form of cross-section to be the best; the square-tipped thread, on the other hand, as advocated by the metrical system, has proved unsuccessful. It has been thoroughly tried by Sellers in the United States, where it has been found practically impossible to produce a good thread by screwing apparatus, the sharp corners on the taps and dies rapidly break away, when a very imperfect thread must naturally follow. The present state of affairs in America conclusively shows the system to be a failure, and all the leading machine tool-makers there are supplying nothing but the V-shaped thread very similar to Whitworth's."

The Sellers threads are, indeed, "very much used," as they are the standards of the United States army and navy, and of the Master Mechanics' and Master Car-Builders' Associations, and of most of the large railroad shops at least. That "all" the leading tool-makers are supplying "nothing" but the V-thread "very similar to Whitworth's," is a fabrication, by some one, out of the whole cloth. The facts of the case are, that from eighty to ninety per cent. of the taps and dies sold by various dealers are already of the Sellers Standard, and the remainder of a plain V-thread, the latter having

been formerly universal, and being still quite largely in the majority, taking the whole United States together. That the Sellers Standard is, in any sense of the word, going out—and still less that it has practically gone out, as *Engineering* explicitly asserts—is utterly untrue. On the contrary, it is coming in. There is little room for doubt that its use is becoming more general every day, and it would now be hard to find a railroad anywhere on which it would not be asserted, at least, that the Sellers (or "M. C. B.," or "United States," as it is variously known) Standard was in use. Many more will assert that they use it than actually do use it, but that is natural.

The comparative merits of the Whitworth and Sellers Standards we are not discussing. This, however, we may say, that records, as respects durability and adherence to standard, are being made every day with taps and dies of the Sellers Standard, which certainly have not been, and probably cannot be, surpassed or even approached. The "sharp" angles (120°) do not, so far as we have ever heard, or can learn, give any difficulty from breaking off, while they do enable the standard to be exactly reproduced and readily maintained, so that complete interchangeability is assured. As it now appears quite certain that it will come into practically universal use in America, and as there is no prospect that any other standard will, anything calculated to impede its, so far, continuous progress to that end is greatly to be regretted. Fortunately, *Engineering's* assertions are so exaggerated, and—to anyone familiar with American practice, palpably false—that they are calculated to disprove themselves.

To make assurance doubly sure in this matter, we addressed an inquiry to the Pratt & Whitney Company, of Hartford, Conn., famous throughout this continent, and, we should imagine, throughout the world, not only for the magnitude and excellence of their products, but for their exertions and success in turning out minutely exact standards of various kinds, and especially for screw-threads. We risk little in saying that no house in the world is better qualified by experience to form correct conclusions in such a matter. The following is their reply:

"Referring to *Engineering's* comments on the second objection brought up by the commission and the Karlsruhe Society against the Whitworth thread, viz.:

"'(2.) The Whitworth system being measured in inches, it is inconvenient for metrical measurements.'

"We would say that if the writer had been aware of the fact that the British Board of Trade had established *in decimal sizes* all Birmingham gauge dimensions—in effect on and after March 1, 1884—he would not have made such a senseless assertion as is there given.

"'If a new universal system of screw-threads must be adopted, then it should not be tied down to any special system of measurement, but should rather be designed on a system of standard gauges of various grades, similar to our Birmingham wire-gauge system.'

"In regard to the disposal by *Engineering* of the third objection raised to the Whitworth thread by the Karlsruhe Society, viz., (that it is difficult of manufacture) a method of disposal, which has justly aroused your indigna-

tion and our own, we can also say that the Sellers or FRANKLIN INSTITUTE Thread, now generally known as the United States Standard, is, in every respect a more practical form of thread to maintain to gauge than the old V-thread, or even the Whitworth, and is a much more simple thread to produce by machinery or the ordinary work-shop tools than the latter form.

"As to the Sellers thread being 'a failure,' will only refer to the fact that in our large and increasing production of taps and dies for the market in this country, *ninety per cent.* are United States Standard, while many not strictly United States Standard in number of threads per inch, are so in form of thread, *i. e.*, one-eighth of the pitch flat, top and bottom.

"V-threads and over-size threads are *not* used to the extent they once were, thanks to the untiring devotion of the Master Car-Builders' Association, through their committee having this matter in charge; and it is now an accomplished fact that bolts and nuts are interchangeable throughout the United States, which previously was not possible with the old system of V and over-size threads.

"Furthermore, a United States Standard tap made in the proper manner will cut *ten times* as many nuts as will one simple V-thread, without appreciable change of size as compared with a standard gauge.

"The United States Standard form of thread embodies a condition which makes this great lengthening of the life of a tap possible, and this is not nearly so easily accomplished in the Whitworth thread. At all events, it is impracticable in the latter form to carry out the conditions referred to, and an impossibility in the V-thread.

"As to the objection regarding relative strength of the bolt cut with the United States Standard or the Whitworth thread, we can refer to the United States Navy Board report of May 9, 1868, which conclusively shows this objection to be unfounded. "THE PRATT & WHITNEY COMPANY.

("GEORGE M. BOND, *in charge of Gauge Department.*")

This is not the first time that facts and figures as to American practice have been "evolved from the inner consciousness" of writers across the water, to suit the occasion, but it is not often that such a complete perversion and reversal of the facts is given currency in a journal of standing. In addition to the railroad shops, the Baldwin Locomotive Works, and nearly, if not quite, all the other large locomotive shops, are using the Sellers system, as are also most of the car shops. Hoopes & Townsend, of Philadelphia, the largest single manufacturers of track bolts, are also using it. The prospects are excellent that the system will come into universal use, as it is now in large and rapidly increasing use. A correction would, therefore, seem to be in order.—*Railroad Gazette, Sept. 24, 1886.*

I have taken this method of replying to your inquiry as best calculated to answer the allegations made in (London) *Engineering*, of September 10, 1886, and have only to add, that, from the letters and publications above referred to, it must be evident that the Sellers or FRANKLIN INSTITUTE Standard for pitches and form of

thread is accepted and used throughout the United States, to the exclusion of any other; that is to say, while there are still some parties who have not adopted any standard, there are none who have adopted any other standard than the Sellers.

Hoping you may find the information herewith forwarded to be a satisfactory answer to your inquiries, I have the honor to remain, Yours respectfully,

WM. H. WAHL, *Secretary.*

BERLIN, W., den 19. Februar, 1887,
Wichmannstrasse 14.

Herrn WM. H. WAHL, *Secretär des* FRANKLIN INSTITUTE, *Philadelphia.*

SEHR GEEHRTER HERR:—Zu grossem Danke sind wir Ihnen verpflichtet für die grosse Mühwaltung, der Sie sich infolge unseres Gesuches vom 22. October, v. J, unterzogen haben, und für Ihre inhaltreiche Sendung vom 31. Januar, d. J., welche zugleich unser Frg. vom 14. dieses Monats erledigt. Wir sind dadurch in die Lage versetzt, unsere Bestrebungen für ein einheitliches Gewinde von Sellers'scher Querschnittsform auf den Vorgang in Ihrem Lande zu stützen und den falschen Darstellungen englischer Zeitschriften entgegenzutreten, welche der nationalen Eitelkeit wohl etwas mehr Rechnung tragen, als recht und billig ist.

Mit Freuden stellen wir Ihnen unsere Gegendienste zur Verfügung und zeichnen, Hochachtungsvoll,

DER VEREIN DEUTSCHER INGENIEURE,
Th. Peters.

[*Translation.*]

BERLIN, W., February 19, 1887.
Wichmann Street, 14.

WM. H. WAHL, *Secretary* FRANKLIN INSTITUTE, *Philadelphia.*

DEAR SIR:—We owe you many thanks for the painstaking manner in which you have attended to our request of October 22, 1886, and for your valued sending of thirty-first of January, 1887, which also answers ours of the fourteenth of February, 1887.

With the facts now in our possession we are enabled to support our efforts for the introduction of a standard thread, having the Sellers form of cross-section, upon the precedents established in your country, and to reply to the false representations of the English journals, which incline rather to the gratification of the national vanity than to what is right and proper in the premises. We gladly place ourselves at your disposal for a return of favors, and remain,

With high esteem,

THE SOCIETY OF GERMAN ENGINEERS,
Th. Peters.

RAINFALL AND WATER-SUPPLY.

By John Birkinbine.

[*A Lecture delivered before the* Franklin Institute, *Friday, February 4, 1887.*]

The Lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Ladies and Gentlemen:—The close relation, or rather, we might say, inseparable connection between rainfall and the procurement of a supply of water for public or domestic uses, while recognized in a general way, is far from being appreciated; and we are apt to forget that all available permanent water-supply is directly traceable to rainfall. Perhaps you will correct me, and advise the use of the terms "directly or indirectly," but we are probably justified in using the term "directly." Nature's laboratory is not a secret one; we can see, if we will, the methods which are employed to accomplish certain ends; and can notice the direct connection between rainfall and all water-supply. We admit that all visible streams or water-courses are immediately traceable to the rain which falls upon their respective drainage areas; and the many unseen or underground streams (the presence of which are determined by various methods which expose the formation of the earth), also owe their existence to certain territories upon which the rain is precipitated, and which are underlaid by certain stratifications of rock or to bodies of water which intercept these strata. The geological structure of a specific district, therefore, naturally affects the water-bearing strata and their position in relation to the surface; but it is generally the disturbed condition of the rocks which causes these subterranean waters to rest in basins or pools, or to find vent as springs. Although where the stratification is regular, and its seams or crevices are continuous, water is often obtained at great depths, apparently beyond the influence of rain, or, as far as can be determined from any connection with other reservoirs, the source from which this water comes, and that which maintains its flow, is the rainfall.

Whether as a gentle shower, or as silently-falling snow, or as a rain-storm, all precipitation of moisture has for its ultimate effect

the production of a proper proportion of water for the growth of vegetation and for the use of mankind, and the quantity of water represented by a given rain- or snow-fall, can be but imperfectly understood or appreciated. Calculations of the volume, weight and power necessary to elevate the water will astonish an investigator, and it is my desire to present, if possible, some conception of the force thus represented.

No attempt will be made to estimate the power which condenses and holds one volume of oxygen and two volumes of hydrogen into a volume $\frac{1}{1800}$ of the space which they fill as gases; for it is claimed that to reduce oxygen and hydrogen to the form of water a pressure of 40,000 pounds per square inch is required. And here we may refer to the fact that Faraday demonstrated that to decompose one drop of water required as much electricity as is contained in the thunderbolt. We will, however, consider the power which is apparently more within our comprehension; namely, that of vaporization, which, while not changing the compound of the two gases, transforms water [which is heavier than air] into vesicles or vapor which is carried to great heights above the earth, and wafted by winds for thousands of miles over the surface of the globe. When we remember that by far the greatest amount of evaporation is near the equator, and that the ocean is the reservoir from which the rains are produced, we may form some idea of the work done, but a very inadequate conception of the power employed.

The presence of water in the atmosphere, which as a great gaseous sea, forms an envelope surrounding the globe, is appreciable in so many ways, that it is remarkable this presence is so often forgotten by us. The dew on the blade of grass, the frost on the window, the brilliant colors of the rainbow, the fog on the ocean, the mist in the valley, the majesty of the cloud bank, the rain, the hail, the snow, all are constant evidences that we exist in an atmosphere in which water is always present in appreciable amount, the quantity of water varying with location, surroundings, temperature, etc. The general composition of the atmosphere is given in *Miller's Elements of Chemistry*, as follows:

	Volumes.
Oxygen,	20·61
Nitrogen,	77·95
Carbon dioxide,	0·04
Aqueous vapor (average),	1·40

It contains also traces of nitric acid, ammonia and carburetted hydrogen. The total weight of water in the atmosphere surrounding the earth is estimated to be 54,460,000,000,000 tons; a weight of which we can form no conception, much less realize how it can be held in suspension, as it were; for the air is a mixture and not a chemical compound, or a distinct substance like water. Prof. Cooke, of Harvard, says: "We may regard the globe as surrounded, by at least three separate atmospheres—one of oxygen one of nitrogen, and one of aqueous vapor—all existing simultaneously in the same space, yet each entirely distinct from the other two, and only very slightly influenced by their presence. Oxygen and nitrogen cannot be reduced to liquids even by the intense cold of the poles. The slightest reduction of temperature, however, when the air is saturated with moisture, is sufficient to condense a portion of the vapor to water and to shower it in drops of rain. On the other hand, when the temperature rises, the heat converts more water into vapor, and the aqueous atmosphere is replenished. Thus it is that the atmosphere of aqueous vapor on the earth is liable to very great fluctuations, from which the Creator has protected the great mass of the air by endowing oxygen and nitrogen with the power of retaining the aëriform condition under all circumstances, and the fluctuation in the one case is as important as the stability in the other." *

The presence of moisture in the air is made constantly manifest to the sense of sight, particularly by sudden changes of temperature; but often there are circumstances which attract attention where the conditions are in whole or in part produced by artificial means. A very marked instance of this was noticed in starting an iron works in New York State last winter, when the thermometer for a week seldom indicated a temperature above zero, and for days averaged — 10°. When doors were opened and the cold dry air rushed into rooms which were warm and moist, clouds of vapor were produced, which filled the apartment as with steam, and such in reality it was. In several instances snow was the result. To prevent freezing, the machinery was kept in motion in advance of the requirements, and the air from the blowing-engine was allowed to escape through a safety vent. When all was in

* *Religion and Chemistry*, p. 71.

readiness, it was found impossible to close this valve, owing to the ice, one inch in thickness, which had formed on it by the moisture in the air which passed through the blowing-engine, and came from a warm room, being condensed and congealed by the lower temperature of the outside air.

In Mr. Lorin Blodget's work on *Climatology*, he states that, "for much the larger area of the United States, and for all portions east of the Rocky Mountains, the distinguishing feature of the atmospheric precipitation in rain is its *symmetry and uniformity in amount over large areas.* The quantity has rarely or never any positive relation to the configuration of the surface, which would identify it with the distribution of Western Europe and the North Pacific Coast; and, in contrast with these, it has a diminished quantity at the greater altitudes generally, and the greatest amounts in the districts near the sea level. It also differs from these districts, and from large land areas generally, in having a greater amount in the interior than on the coasts for the same latitudes, at least as far north as the forty-second parallel of north latitude."*

We must not interpret this extract too literally, for they are generalizations and we cannot overlook many local influences which affect the rainfall. To a considerable extent, the position of the rain-gauge influences the quantity of precipitation measured, for series of careful records, taken at various localities, and covering considerable periods of time, indicate that the quantity entering the gauge, diminishes irregularly with its height above the ground; probably on account of the greater wind velocity at the higher level. One authority asserts that, at a height of twenty feet, this decrease amounts to as much as ten per cent. of the entire rainfall; and one exceptional case is recorded where the measured precipitation at an elevation of fifty feet, was but forty per cent. of that at the earth's surface. Our water department has attempted to construct a curve showing this decrease from its own observations, as well as from reported experiments; this curve demonstrates that at an elevation of forty feet above the ground eighty-seven per cent. of the actual rainfall enters the gauge. Commenting upon the question, why there is less rainfall caught in gauges high above the ground than in those on the ground, Prof. Cleveland Abbe, in his lecture in December last, upon "Popular Errors

* *Climatology of the United States*, p. 317.

in Meteorology,"* says: "There is really the same amount of rainfall at 100, or 50 feet altitude as on the ground; the fault is in our rain-gauge which is exposed to stronger winds when set high up, and to almost no wind when flush with the ground. The stronger winds deflected around the gauge carry the drops to one side, and hence the higher gauge catches less than the lower one."

The variations are prominently shown in the annual report of the Philadelphia Water Department for 1885, in which the average recorded precipitations for the years 1883, 1884 and 1885 are given as follows: (The percentages refer to the United States Signal Station as a standard.)

U. S. Signal Station,	37·25 inches,	percentage	100
Philadelphia Water Department,	35·29 "	"	95
Pennsylvania Hospital,	42·72 "	"	115
Germantown,	41·25 "	"	111
West Chester,	50·59 "	"	136
Pottstown,	44·52 "	"	119
Reading,	42·91 "	"	115

There are other localities mentioned in the report, but I have selected those which are nearest to the city, and we will consider only the first three, which are within the limits of the city, and are taken where it is presumed all possible precautions against error are provided for. These three show a variation in the average, for the three years, of 6·43 inches of rain, and, if we select monthly records, the differences are even greater than the average, as the following will demonstrate: In August, 1885, the U. S. Signal Station reported 6·80 inches, the Water Department 7·90, and the Pennsylvania Hospital 10·08 inches, a difference between extremes of 3·28 inches. In the months where the rainfall is not so heavy as in August, the differences are scarcely less marked. Thus, the following are recorded:

	U. S. S. S.	*W. Dept.*	*P. Hospital.*			
November, 1884,	2·31	2·98	4·01,	a difference of	1·70	inches.
In October, 1885,	3·33	3·67	4·85,	"	1·52	"
In December, 1884,	3·28	3·78	4·76,	"	1·48	"

It is not my purpose to take up the subject of rainfall generally, although the topic for the lecture might possibly have given

* See this JOURNAL, **123**, 115.

rise to such expectation. The purpose of the lecture would be better expressed by the more prolix title, "The Water which Falls upon and which is Required by the City of Philadelphia"; and we will now consider the first branch of the subject, which was suggested by the favor with which an article,* entitled "Sun Pumping," prepared for one of our technical journals, was received.

THE WATER WHICH FALLS UPON PHILADELPHIA.

Have you ever thought of the volume, or the weight of the water which is annually precipitated upon the area covered by the city in which we live; or even upon the quantity which falls upon a square mile or a square acre? If not, the amount will be a surprise, and, at the risk of appearing to treat the subject in an elementary manner, I will ask you to follow some calculations which will possibly give an idea of the volume of water, most of which the sewerage system of a great city must care for, the work done by the sun in elevating the weight to the cloud-level (if such a term is admissible), and the relation that the rain falling upon the city bears to the water supplied to it. Let us first consider the precipitation upon an acre and a square mile:

In a square acre there are . . . . . 43,560 square feet.
" " mile " (5,280 × 5,280) = 27,878,400 " "

Therefore, each foot of rain which falls upon these areas is equivalent in volume to—

43,560 cubic feet, or 325,829 gallons of water per acre; and
27,878,400 " " " 208,530,432 " " " " square mile.

Now, in round numbers, thirty-two cubic feet of water, under ordinary conditions and temperature, weigh one net ton (2,000 pounds), and thirty-six cubic feet weigh one gross ton (2,240 pounds). On this basis, the weight of water can be readily calculated; however, as the usual method of reporting the rainfall is in inches and not in feet, we may first bring the above figures to this base.

For each inch in depth of rain, the figures per acre and per square mile are as follows:

	Volume.	*Weight.*
Per acre,	3,630 cubic feet, or 27,152 gallons	= 100·8 gross tons. [113·4 net tons]
Per sq. mile,	2,323,200 cu. ft., or 17,377,536 gals.	= 64.533⅓ gross tons. [72,600 net tons.]

**Iron Age.*

On the authority of Chief Engineer and Surveyor Mr. S. L. Smedley, the entire area covered by the city, is $129\frac{888}{1000}$ square miles, and if we multiply the volume and weight of water per square mile representing one inch of rainfall, by the area of the city, we have the following :

Volume.

309,582,586 cubic feet, or 2,248,357,740 gallons.

Weight.

8,349,516 gross tons, or 9,393,206 net tons.

This weight is only appreciable by comparing it with the quantities of materials with which we are familiar. During the year 1886, the anthracite coal district of Pennsylvania produced over 33,000,000 gross tons, a larger output than ever before; and, as far as the product is concerned the year was also the greatest in iron production, viz., 5,684,543 gross tons. But four inches of rain on the area within the corporate limits of the city of Philadelphia, weigh as much as all of the anthracite coal mined last year in this state; and one inch of rain upon this area represents a weight nearly fifty per cent. greater than the total output of pig iron in the United States in 1886. The wheat crop of the United States for 1886, estimated by the Department of Agriculture at Washington at 457,000,000 bushels, weighs about the same as one and one-quarter inches of rain on the area of this city.

From the table of the means and extremes of rainfall, as observed at the Pennsylvania Hospital, we find that the annual average for fifty-seven years was 45·19 inches, or 3·766 feet.

TABLE OF THE MEANS AND EXTREMES OF RAINFALL AT THE PENNSYLVANIA HOSPITAL, PHILADELPHIA, COMPILED FROM THE RECORDS FROM 1830 TO 1886, BOTH YEARS INCLUDED.

	Average Rainfall in Inches.	*Maximum Rainfall in Inches.*	*Minimum Rainfall in Inches.*
January,	3·577	7·837	0·730
February,	3·160	6·615	0·551
March,	3·551	6·985	1·087
April,	3·524	7·750	0·585
May,	4·031	8·685	1·070
June,	4·142	11·025	0·887
July,	4·177	11·805	0·985
August,	4·729	15·816	0·620
September,	3·645	13·904	0·249

	Average Rainfall in Inches.	*Maximum Rainfall in Inches.*	*Minimum Rainfall in Inches.*
October,	3·324	10·050	0·447
November,	3·566	9·025	1·036
December,	3·764	7·378	1·044
Winter,	10·500	15·370	4·711
Spring,	11·167	17·650	6·594
Summer,	13·047	29·228	6·256
Autumn,	10·526	18·011	3·359
Year,	45·190	61·135 (1867)	33·240 (1834)

We can now estimate the weight and volume of the average amount of rain which annually falls on the city, as follows:

Volume.

For the year, 13,580,327,043 cubic feet, or 101,603,286,282 gallons.

Weight.

377,314,640 gross tons, or 424,478,970 net tons.

In *Stahl und Eisen*, Prof. Ehrenwerth estimates that the total annual coal production of the world approximates 400,000,000 tons (metric).

Therefore, if we accept Prof. Ehrenwerth's figures as correct, the rain, which has fallen annually on the area of Philadelphia, has averaged over ninety-five per cent. of the total coal output, at present, of the world.

Upon the assumption of a uniform distribution of the precipitation throughout the year (a condition which the table shows, and which we know, does not exist), the daily average for the fifty-seven years under consideration, would be:

Volume.

37,214,595 cubic feet, or 278,365,171 gallons.

Weight.

1,033,739 gross tons, or 1,162,956 net tons.

But the table demonstrates that in the year 1867 as much as 61·135 inches of rain fell, which would increase the above amounts over thirty-five per cent., and that in the year 1834 but 33·24 inches of rain are reported, which is about seventy-three per cent. of the average precipitation, and the figures, as above, for that year would be but seventy-three per cent. of those given. It will be noted that the average rainfall occupies a point very nearly midway between the two extremes above given; this mean between the extremes is 47·188 inches.

Similarly the maximum and minimum monthly precipitations

indicate variations from these figures, but, for the present, we will consider only the minimum monthly rainfall to estimate a possible daily average from it, leaving the maximum to actually recorded severe rain-storms; for the rainfall has ranged from *nil* to 7·323 inches in a day. Taking the minimum monthly rainfall from the table, viz., September, 0·249 inches, the daily average on the assumption of uniform distribution throughout the month is 0·0083 inches, which indicates that for any one month the minimum amount of water falling per day on the city of Philadelphia was:

Volume.

2,494,835 cubic feet, or 18,661,369 gallons.

Weight.

69,301 gross tons, or 77,963·5 net tons.

(or probably less than the evaporation from the area of the city in the same time.)

To consider the maximum rainfall, we look up the records of severe rain-storms, and by reference to the Pennsylvania Hospital reports, we find that from and including the year 1840, there were twenty-seven days on which over three inches of rain fell. The greatest amount being 7·323 inches, which are reported as falling during the twenty-four hours in August, 1873; the next in August, 1867, with a record of 6·680 inches, and in August, 1860, 6·005 inches. On two consecutive days (the 22d and 23d) of September, 1882, 5·566 and 4·260 inches, respectively, fell, a total for the two days of 9·826 inches. Of the twenty-seven days, on which over three inches of rain fell, eleven were in August, four in June, three in October and September, two in April and November, and one each in January and July; the heaviest of these last two being a fall of four inches in January, 1875.

Most of the large precipitations above mentioned, continued but for a portion of a day; in fact, many of the records mentioned are for precipitations lasting but part of a day. Some of these will be noted later.

If, for the purpose of forming an appreciation of the enormous quantity of water represented by one of these heavy down-pours, we take the latest recorded one for a day, viz., August 4, 1885, 4·46 inches, we find that it was equivalent (for the area of Philadelphia) to a

Volume

of 1,340,598,334 cubic feet, or 10,027,675,520 gallons, and

Weight

of 37,238,843 gross tons, or 41,893,698 net tons.

Or, to make the amount appreciable, such a storm as that mentioned, when less than four and one-half inches of rain fell in a day, deposited on the area of Philadelphia, a weight of water greater by over twelve per cent. than the total amount of anthracite coal mined in 1886; and this weight of water represented more than half of the weight of the total crop in 1886 of corn, wheat and oats.

The volume would be over one-fourth of that of the great storage dam proposed for the Croton Aqueduct at Quaker Bridge, to cost the City of New York, $7,000,000.

The automatic recording water-gauge, connected with the office of the Water Department, at Thirteenth and Spring Garden Streets, shows that on the morning of November 18th last, 0·52 inches of rain fell in nine minutes; and a similar gauge, located at Doylestown, indicated, on August 3, 1885, a fall of one and one-half inches of rain in twenty minutes. It is unnecessary to follow calculations further to form a conception of the amount of water represented by such precipitation; but it will be interesting to note that a rainfall, over the area of Philadelphia, such as that recorded last November, is equivalent to a flow of 290,000 cubic feet per second; which is 15,000 feet per second more than the reported average flow of water over the falls of Niagara.

If time permitted, we could follow the subject of the weight and volume of water which falls upon nearly 2,000 square miles of drainage area of the Schuylkill River, of which but about forty per cent. passes Fairmount Dam, giving an average daily flow for the river, at ordinary stages, of less than three times the average daily precipitation on the area of Philadelphia above determined.

It has been the desire to draw our minds to an appreciation of quantity and weight, and I would now ask that you follow me to a conception of the *power* represented by the rainfall upon the area of our city, or, if I may use the term the "Horse-power employed in Sun Pumping," for as Guyot says, in *Earth and Man:* * * * "The Sun, the great awakener of life, the king of Nature, shoots his burning rays every day athwart the waters. He causes the invisible vapors to rise, which, lighter than the air itself, unceasingly tend to soar into the atmosphere, filling it, and constituting within it another atmosphere. In their ascending movement, they encounter the colder layers of the higher regions of the atmos-

phere, which perform the part of coolers. They are condensed in vesicles, that become visible under the form of clouds and fogs. Then borne along by the winds whether invisible still, or in the state of clouds, they spread themselves over the continents and fall in abundant rains upon the ground which they fertilize. * * * To study the distribution of the rains and of the moisture on the surface of the globe, is to study the course of the winds which are their carriers"*

The power that is required to convert the water into vapor and lift it far above us, can be but imperfectly understood; but to form a conception, let us consider merely the elevation of the water to the cloud level. Prof. Loomis, in his text book on *Meteorology*, gives the average height of the clouds as two miles; we know that some of the clouds which drop their rain upon the earth are much lower than this, but we do not know how high the water was raised, nor how far it was carried before intercepted by the cooler stratum that made the vapor visible as cloud. Let us then assume the average height to which the water, (which as rain falls on Philadelphia) is elevated, to be 10,000 feet; and, using the figures with which we have become somewhat familiar, attempt to estimate this power. If our estimate of height is excessive, it is capable of reduction by the decimal system to any amount required.

Hann is given as the authority for the statement that five-tenths of the aqueous vapor is found within the stratum between the sea level and 6,500 feet above it, and that nine-tenths of the vapor is below 20,000 feet. It is asserted that from a series of balloon and mountain observations, he formulated the following general table:

Altitude above Sea Level.	*Proportionate Quantity of Aqueous Vapor.*
1,000 feet,	1·00
2,000 "	0·87
3,000 "	0·73
4,000 "	0·64
5,000 "	0·56
6,000 "	0·56
7,000 "	0·48
8,000 "	0·42
10,000 "	0·34
12,000 "	0·27
14,000 "	0·23
16,000 "	0·18
18,000 "	0·16
20,000 "	0·13
22,000 "	0·07

* *Earth and Man*, p. 130.

This is referred to, that you may note a possible error in the assumption, but as we know that many of the lower strata of clouds are evanescent, and are dissipated by the sun's rays, while most of our rains come from clouds at a greater elevation, we will make the estimates on the assumption that all of the vapor which falls as rain has been raised to an average height of 10,000 feet; for the object of these estimates is rather to form a conception of these forces of nature, than to give absolutely exact figures.

To make the estimates of power, let us use the familiar standard of 33,000 pounds raised one foot high per minute as one horse-power, and apply the formula:

$$\frac{\text{Net tons per day} \times 2{,}000 \text{ lbs.} \times 10{,}000 \text{ feet}}{33{,}000 \text{ foot-pounds} \times 1{,}440 \text{ minutes}}$$ equals the HP. developed.

It is only the developed horse-power which we shall consider, and no allowances will be made for losses of any kind.

We, therefore, have the following figures to represent the horse-power to be developed in raising to a height of 10,000 feet the quantities of water represented by the precipitation of—

	Horse-power.
One inch of rain on one acre,	47·7
" " " " " " square mile,	30,555
" " " " " 129·383 square miles (the area of Philadelphia),	3,953,370
The average daily precipitation of the month of minimum rainfall (0·249 inches) on the area of Philadelphia,	32,812·9
The average daily rainfall, calculated from the annual average (45·19 inches) on the area of Philadelphia,	489,460
The maximum rainfall recorded in twenty-four hours in fifty-seven years (7·323 inches) on the area of Philadelphia,	28,950,524

To understand what these powers represent, we can best refer to the volume of the last census on manufactures, in which the total amount of steam- and water-power employed in 85,923 establishments reporting was 3,410,837 horse-power, of which 2,185,458 horse-power was steam-power, and 1,225,379 horse-power was water power. Therefore, if the census returns are considered to represent developed power, the entire manufacturing industry of the United States, as given by the census returns, has not sufficient

power connected with it, to raise in one day the water represented by one inch of rain on the area of Philadelphia and the entire steam- and water-power, as reported in the census, could not, in working together for twenty-four hours, develop more than twelve per cent. of what we have estimated as necessary to raise the 7·323 inches of rain which fell in one day over the area of Philadelphia to a height of 10,000 feet. To form an idea of the "sun-pumping" represented by a severe rain, such as above mentioned, when 0·52 inches of rain fell in nine minutes; we find that to raise an equal amount in the same time to a height of 10,000 feet would require the development of 329,000,000 horse-power. Now, if we apply Fairbairn's formula of "one cubic foot falling twelve feet per second equal to one horse-power" to Niagara Falls, where 275,000 cubic feet per second fall 230 feet, we find that the entire power which this immense cataract could produce in nine hours, would be scarcely sufficient to elevate to cloud-level the water which fell in the city of Philadelphia in the nine minutes above mentioned. In these general estimates, no allowances of any kind are made. I would offer one more comparison; at the western extreme of Lake Superior, close to the City of Duluth, the St. Louis River, a stream about double the volume of the Schuylkill River, falls in a distance equal to that from Manayunk to the Fairmount dam, from a height 100 feet higher than the Roxborough hill to tide level. And yet, upon the basis of one cubic foot falling twelve feet per second, this magnificent, but as yet undeveloped stream would supply but one-fourth the power to raise the average daily rainfall on the area of the city.

We can form another idea as to what the rainfall upon the area of the city of Philadelphia amounts to, which will probably be even more satisfactory than the calculations as to horse-power. The usual method of rating pumping-engines, is by the duty in pounds of water raised one foot high by the consumption of 100 pounds of coal; and although some tests have shown duties in excess of 100,000,000 foot-pounds, we shall consider that a sufficiently high basis for estimation, for it is much above the average work performed by the pumping-engines in the United States. If, therefore, we assume a duty of 100,000,000 foot-pounds, we will have for each gross ton of coal consumed 2,240,000,000 pounds of water raised one foot high. To elevate the water, (which fell as rain,) to

the cloud-level, say 10,000 feet, the following amounts of coal would be consumed:

	Gross Tons.
One inch of rain on one acre, ...	1·008
" " " " " one square mile, ...	645·33
" " " " " area of Philadelphia, ...	83,495·
45·19 inches of rainfall on the area of Philadelphia (that is, the average for fifty-seven years), ...	3,773,146·

That is, to raise the average amount of water, which has fallen annually upon the areas of the city of Philadelphia for the past fifty-seven years, would require the yearly consumption of 11·4 per cent. of all the anthracite coal mined in 1886, using the most improved pumping machinery.

Or, on the assumption of the same rainfall in the anthracite region as at Philadelphia, one-half of the total production of coal at the present mine development, would be consumed in raising the water, which falls as rain upon the 470 square miles of the anthracite region.

I recognize that in all of the calculations presented, there are many possible sources of error, and would therefore again remind you that they are intended as comparative and not as absolute estimates; their object being solely to present a conception, imperfect though it be, of the forces which are continually at work about us.

THE WATER WHICH IS SUPPLIED TO PHILADELPHIA.

No subject is of greater interest to each of us than the character and quantity of our water-supply, for on these depend largely our comfort, safety and health. It is not essential that we should enlarge upon this, nor will I consider it necessary at the present time to refer to the chemical analyses which have from time to time been published. That it is not all that we desire, is too well recognized to need mention; the presence of mud discoloring it, or the shortage in certain districts when heavy demands for fires, etc., have been made, are convincing proofs that an improvement is necessary; but that it is as unsatisfactory as some have asserted need, on the other hand, scarcely be noticed. However, a subject of so much importance cannot be too thoroughly discussed; but while we should look at it in all candor for the weak points, we should be equally frank in admitting the merits of the supply

upon which we depend. Those of our citizens, whose business calls them to various parts of our own country, or to foreign lands, and who have opportunities for observing the peculiarities of their own and foreign cities, cannot but agree that an absence of local pride seems to be pre-eminent among our citizens, and that we seldom or never "put our best foot forward." We are too apt to display our disadvantages, and to make light of our advantages, and in no one thing is this more pronounced than in some of the statements concerning our water-supply, which have obtained publicity. Several years ago, our deficiencies in this line were heralded throughout the country to our disadvantage, until, as one, familiar with water-supplies, facetiously remarked: "We were drinking poison, and our pipes had so *shrunk* in diameter that the supply was both unhealthy and inefficient." That the case is not as bad as this is evident from the fact that, although the year just past was one of unusually large water consumption, and that during the season of the greatest demand, there was a severe drought, few complaints of either the quality or quantity of water were heard. It is not my desire to be understood as asserting that we should not have a better water supply; on the contrary, it should command the most earnest and immediate attention of our city authorities; but the wholesale condemnation of what we now have, and the dire predictions as to the future which are published, are beyond the truth, and some of them are apparently instigated in the interest of special schemes.

Familiarity with the Schuylkill and Delaware Rivers, from which our supply of water is obtained, encourages one to appreciate their disadvantages; but the knowledge of their drainage areas, gained by tracing many of the various tributaries from their sources to their confluences with the rivers, and an intimate acquaintance with the industrial development of the region, permit me also to recognize their merits. No more reliable source of water-supply is obtainable than from a stream of considerable size, particularly if the water passes over rapids, or by falling over dams, etc., is exposed to aëration. But the otherwise available character of river water may, and in our case is, offset by deleterious drainage. This is particularly true of the Schuylkill River, from which over ninety per cent. of our supply is obtained; but some of the deleterious drainage which enters into it, fortunately for us, neutralizes other objectionable features.

Without entering into details of the drainage of the Schuylkill River, we may follow it from its source, in the anthracite coal regions, where it becomes so strongly impregnated with acid from the mines as to interfere with the life of fish, etc.; but this same acid destroys the organic matter emanating from a populous district probably as far as Reading. In the neighborhood of Reading, large tributaries draining a limestone formation enter the river, and so neutralize this acid that at Pottstown, forty miles above Philadelphia, the water which is supplied to that city from the river is comparatively unobjectionable. Below this point, Phœnixville, Norristown and Conshohocken likewise, obtain their water supply from the river; but they also add to its impurities a considerable amount, which would be greater still had they efficient sewage systems. The discoloration of the Schuylkill water (outside of the mill refuse, which could and should be largely prevented), comes principally from the streams which enter the river between Norristown and Pottstown, and which, while objectionable, is not positively injurious. The large volume of purer water brought to the river from tributaries below Norristown, and possibly the limestone streams in that vicinity, have a marked effect in the improvement of our water-supply as to potability. Our present water-supply is objectionable more from its mechanical than from its chemical impurities, and with proper methods for the prevention of objectionable matters entering the river, with ample settling capacity provided, with possibly aëration by mechanical means, our water-supply will continue to be above the average of that furnished to large cities. To-day, there is much that is objectionable to our senses, as well as to investigation, which can be removed. But as the city grows, the surrounding country will be more densely populated; the pollution of the stream being increased by the augmented population and industries, and it is probable that it would be much cheaper to construct a system of supply obtained from sources which can be more readily controlled from contamination, than to attempt to maintain the purity of the river in the distant future. It is here that a study of the rainfall is essential to the determination of a suitable water-supply, and it will be necessary in providing for the future to select a source whose purity can be maintained, or to adopt a system which will prevent objectionable products from entering the water which is furnished to our citizens.

Those who heard, or who have read, the lecture delivered in this room by Dr. Leeds, will remember that he laid great stress upon aëration of the water supplied to cities, and recommended the use of air-compressors to deliver the air under pressure so as to take advantage of the solubility of oxygen.

He instances results which apparently sustain the statements as to the value of such oxidation, and the advantages of introducing the air under pressure, but if we admit all that is claimed, it is hardly probable that the method can be generally employed, particularly in works already established. He gives as a reason for the compressors which were purchased for the purpose, not being employed at our various Philadelphia pumping-stations, that "At only one of them, * * * has the process been applied, namely, at Belmont, the other mains being too leaky to permit of its being used." It would rather seem that the contours, followed by the lines of pumping-mains from the other works, were of necessity such as would not keep them free from traps in which the air can accumulate, and thus produce jars to destroy the pipes. One of the first rules of good pipe-laying is, wherever possible, to obviate air-traps, and the efforts of an engineer are to prevent the accumulation of air in the pipes, after they are laid. We can, therefore, not expect that with our water-supply as at present arranged, aëration, by means of compressors in connection with the pumping mains will be successful, their use would rather be attended with considerable risk to the pipe system. If the beneficial results from aëration can be maintained, and they are sufficient to command attention if but a portion of the organic matter is thus oxidized, it would appear that better and less risky methods of reaching the desired results would lie—

(1.) In the direction of raising the water above the surface of the reservoirs, and allowing it to fall in cascades, thus exposing it to the air, and, at the same time, adding ornaments to the reservoirs.

(2.) The idle compressors could be utilized by placing them near to, or upon, floats in the reservoirs and forcing the air under pressure into the water near the bottom; or,

(3.) As the lift would be but a few feet, rotary pumps, similar to wrecking pumps, could be placed on floats and large volumes of

water be quickly raised so as to fall in thin cascades and permit of aëration.

Either of these suggestions would appear to be applicable to our existing system of water-supply, and free from the serious objection of air in the pipe system; the disturbance of the water might, however, interfere with the settlement of matter held in suspension; but as our reservoir capacity is insufficient to accomplish any real clarification, of which we have evidence to-day in the color of the water, this would at present be a minor objection. For large storage reservoirs, in which the development of organisms cause unpleasant tastes, or odors, these methods may also be found efficacious.

The total amount of water supplied to the city of Philadelphia in the year 1885, as given in the published report of the Water Department, was 25,165,020,072 gallons, a daily average of 68,945,260 gallons. This amount was raised to an average elevation of 156·2 feet, and the work done was therefore 89,746,351,338 foot-pounds per day; or, on the assumption of continuous work, 62,323,855 foot-pounds per minute, equal to 1,889 horse-power continuously exerted.

Mr. John L. Ogden, Chief Engineer of the Water Department, states that, during the year 1886, the minimum daily pumpage was 49,187,598 gallons, and the maximum 102,202,857 gallons, the average being 78,432,289 gallons per day. If the average height to which this was pumped, was the same as in 1885, the increase would be 13·8 per cent., requiring the continuous development throughout the year of 2,150 horse-power.

Our calculations show that the average precipitation on the area of Philadelphia was equal to a volume of 278,365,171 gallons daily, or about four times the average daily pumpage of last year. Therefore, if we could collect twenty-eight per cent. of the water falling on the area of the city and store it, we would have an ample supply for our present requirements. But the collection of water, without storage, would not avail us, for we must provide for dry seasons, such as that which occurred last year, when from August 8th to October 26th, inclusive (eighty days), the Water Department gauge showed that but 1·578 inches of rain fell, which is equivalent to a deposition on the area of the city of 44,348,856 gallons per day, or fifty-six and one-half per cent. of the average

daily pumpage for the year, and probably less than the evaporation for eighty days.

The problem to be solved by our city authorities in securing a source of future water-supply, is fortunately not a difficult one, for there are several available drainage areas from which a supply of potable water can be obtained; either of which are more than ample for the present requirements of the city. The problem is, rather, how far into the future shall we look, and for how much of posterity shall provision be made? Upon the solution of this will depend also the character of the works constructed, and their number.

The available sources are:

(1.) The Schuylkill River, from which the water must be raised into the reservoirs by pumping, with the attendant constant expense of operating the machinery. To continue the use of this source, persistent precautions against pollution must be taken and provision for storage must be made.

(2.) The Delaware River, by pumping from a point or points away from the influence of the city's sewage. This will require the continual expense of maintaining machinery, increased storage and demand watchfulness against future pollution.

(3.) Gravity supplies from one or more of the tributaries of the Schuylkill or Delaware Rivers, or from the upper waters of the latter stream. Such supply will be dependent upon the rainfall upon the areas drained, the percentage of the precipitation lost by evaporation, infiltration and absorption, and the storage capacity provided. While gravity supplies are generally more costly to construct than pumping works, they are less expensive to maintain, and the territory drained can be more readily controlled.

(4.) Publicity has been given to a project (which will probably never mature) to construct an immense dam across the valley of the Schuylkill, above Manayunk, to act in the double capacity of a store reservoir for a supply of water, and for power. This plan would remove much of the objectionable drainage, by *wiping out of existence* a large proportion of the manufacturing industries, and a considerable part of the town-sites along the river; and bring close to us the possible risk of the failure of the dam. If the damage to industries, to private dwellings, the losses to business centring about the city, and the changes of railroad lines which

this necessitates, are considered in connection with the fact that much of the objectionable drainage would still exist, it will hardly meet popular favor.

When the arrangements for this lecture were made, it was expected that the recommendations of the Chief Engineer of the Water Department as to a future water-supply would have been made public. Such, however, is not the case, but I understand that they will shortly appear and it would be discourteous to anticipate these recommendations; for those to whom have been entrusted the duty of determining what is best to be done, are entitled to a careful consideration on our part of the problems which they have studied out with so much care. But having from boyhood taken a lively and continuous interest in the water-supply of our city, I will be pardoned for expressing the conviction, based upon a careful study of the subject, that Philadelphia will obtain the best and most reliable water-supply by gravitation from one or more of the tributaries of the Schuylkill and Delaware Rivers, and in view of possible social or political disturbances, it would appear that for the future, a supply which did not make the city dependent on one source only would be advisable. To have a proper control of the areas drained, they should be the property of the city, and such purchase would, in view of the rapid reduction of our forest area, be likely to prove a profitable investment. Much of the area drained by these tributaries is imperfectly adapted for agriculture, but, if properly cared for, could sustain valuable forests, which would assist in securing the collection of the water falling as rain, by making the springs perennial, and at the same time grow timber of value. Philadelphia should not only control her water-supply, but also the sources from which it is obtained. A great city maintaining a magnificent forest preserve, wherein tree culture could be carried on both practically and technically, having the double purpose of maintaining the purity of the water-supply and the growth of timber for profit would do much to popularize a much neglected feature of state and national administration.

For whatever knowledge I may possess concerning the present or the future water-supply of the city, I am indebted to him, to whom I also owe the credit of any educational facilities or personal advantages, and it was in assisting my father in the study of the requirements of the city, that my interest in the subject originated.

It is, therefore, a great gratification to find that the results of the examinations, surveys and estimates, made at a large outlay during late years, are so close to those made by him twenty years ago, at an expense of about $5,000. I regret that his life was not spared to allow him to appreciate this, or to have others recognize the fact that his conception of what Philadelphia needed, was but a quarter of a century ahead of what the city must now have.

You may properly credit these statements to loyalty to the memory of my father, and I am proud to admit such fealty as influencing me. But I will ask those of you who may be interested in the subject to compare the results of reconnoisances on foot of the streams convenient to the city, the surveys, calculations and estimates published by him in 1865,* with similar data published as the results of examinations made, at a cost of $80,000, with the most approved instruments, with the help of a large corps of assistants, and with the advantage of twenty years of progress to confirm the above statement.

Either of the subjects embraced in the topic of this lecture are sufficient for an entire evening, and they have been but imperfectly treated. But if the data presented will assist us to recognize how immensely beyond our conception are the forces of Nature, which are constantly about us, if what has been said helps any one to appreciate the omnipotence of the Creator, at whose bidding "there went up a mist from the earth and watered the whole face of the ground," if any thought expressed may aid in securing for Philadelphia of to-day, and the Philadelphia of the future, such a water-supply as a great city deserves; or if any suggestion made will assist in securing your support to any honest endeavor to advance our city, your patience in listening to me will have been rewarded.

---

* *Report upon Future Water-Supply of Philadelphia.* By Henry P. M. Birkinbine, Chief Engineer, 1865.

THERMODYNAMICS.

By Prof. De Volson Wood.

(*Continued from page 209.*)

We next consider the article on intrinsic energy, being article 247 of *The Steam Engine*, by Rankine. The intrinsic energy of a substance is the external work which it is capable of doing in being expanded from a given state as to temperature and volume (or pressure and volume) to that of total privation of heat and indefinite expansion. Since indefinite expansion is impossible in an actual machine, the quantity is *ideal*, but its value may be com-

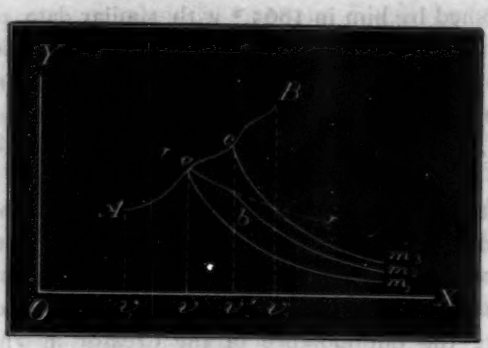


Fig. 3.

puted for the ideally perfect gas, and the algebraic form of an expression for its value be found for imperfect fluids.

It will be necessary, in the first case, to find an expression for the heat absorbed during a change of temperature, as well as of pressure and volume. In our preceding articles, explaining article 241, we found that the expression $\tau \frac{dp}{d\tau} dv$ was a measure of the heat absorbed for an expansion in which the temperature, τ, was constant; but this is only one condition out of an infinite number which may occur in practice. Suppose that heat be absorbed, so that during expansion the relation between the pressure and volume may be represented by the line *A B*, *Fig. 3*; it is required to find a differential expression for the amount of heat absorbed in passing from a to c, when a and c are consecutive points. To find

it, we proceed on the same principle that is used in many cases in geometry—inscribe a polygon, whose properties are known—and pass to the limit. Beginning at a, draw an isothermal $a\tau$, and through c the vertical cv', intersecting $a\tau$ in b; so that, at first, the passage from a to c is along the isothermal ab and the vertical bc. The abscissa of b in reference to a will be $vv' = dv$. Through a, b and c pass the adiabatics am_1, bm_2, cm_3, conceived to be extended indefinitely to the right; then will

$$\text{area } m_1 a b m_2 = \tau \frac{dp}{d\tau} dv.$$

The area $m_2 b c m_3$ represents the heat absorbed while increasing the temperature at the constant volume v', the pressure being increased an amount bc. In this case, the temperature will be increased an indefinitely small amount, represented by $d\tau$. The determination of the heat necessary to increase the temperature by one unit (say 1° F), depends upon an experiment and a calculation, the process of which we will assume is known by the reader; the result of which is called the *specific heat at constant volume*. If the specific heat is constantly varying, it is only necessary to consider its *rate* at b; that is, it will be such a quantity as would increase the temperature 1°, if the specific heat of the substance remained uniform throughout the degree.

Let $K_{v'}$ = the specific heat of the substance at the state b, measured in foot-pounds; then will $K_{v'} d\tau$ be the heat necessary to raise the temperature from that at b to that at c, and

$$\text{area } m_2 b c m_3 = K_{v'} d\tau.$$

Ultimately, when a and c are consecutive, the area abc vanishes and we have, if dH be the heat absorbed in passing from a to c

$$dH = \text{area } m_1 a c m_3 = K_v d\tau + \tau \frac{dp}{d\tau} dv \qquad (1)$$

which is, substantially, Rankine's equation (2), page 310; and is precisely the form given by Clausius for homogeneous bodies.

If, however, the substance is capable of an indefinite expansion, and if the aggregation of the substance does not change during such expansion, and if by an isothermal expansion the substance approximates more and more nearly to a perfect gas, as assumed by Rankine, then may the value of K_v be transformed as follows:

FIG. 4.

We have already found, *Fig. 4*,

$$m_2 b c m_4 = \tau \int_v^{v''} \frac{dp}{d\tau} dv,$$

$$m_2 b c m_3 = K_v d\tau.$$

Similarly

$$m_4 e d m_5 = K_{v''} d\tau$$

$$m_3 c d m_5 = (\tau + d\tau) \int_v^{v''} \frac{d(p+dp)}{d\tau} dv$$

$$= \tau \int \frac{dp}{d\tau} dv + \tau \int \frac{d^2p}{d\tau^2} dv d\tau + d\tau \int \frac{dp}{d\tau} dv + d\tau \int \frac{d^2p}{d\tau^2} dv d\tau$$

$$= \tau \int \frac{dp}{d\tau} dv + \tau \int \frac{d^2p}{d\tau^2} dv d\tau + \int dp dv,$$

the last term of the preceding expression being omitted, it being an infinitesimal of a lower order. We also have

$$\text{area } b c d e = \int dp dv = d\tau \int \frac{dp}{d\tau} dv = m_2 b c d m_5 - m_2 b e d m_4.$$

Substituting,

$$K_v d\tau + \tau \int \frac{dp}{d\tau} dv + \tau \int \frac{d^2p}{d\tau^2} dv . d\tau + d\tau \int \frac{dp}{d\tau} dv - K_{v''}$$

$$- \tau \int \frac{dp}{d\tau} dv = d\tau \int \frac{dp}{d\tau} dv.$$

Cancelling and reducing,

$$K_v = K_{v''} - \tau \int_v^{v''} \frac{d^2p}{d\tau^2} dv = K_{v''} + \tau \int_{v''}^{v} \frac{d^2p}{d\tau^2} dv.$$

The difference between the specific heats at the volumes v and v'' is due to the internal work during the expansion along $c\,d$, exceeding that along $b\,e$.

If v'' be removed so far from v that the gas becomes perfect, then $K_{v''}$ will, according to Rankine's hypothesis, be constant, and we will represent it by C_v in place of his old English k. Further, the expansion necessary to give this result is assumed to be indefinite, so that v'' will be infinite, and also the relation between p and τ is assumed to be a continuous function, for otherwise the integration could not be performed, so that we finally have

$$d\,H = C_v\,d\,\tau + \left[\tau \int_{\infty}^{v} \frac{d^2 p}{d\,\tau^2}\,d\,v\right] d\,\tau + \tau \frac{d\,p}{d\,\tau}\,d\,v \qquad (2)$$

which is Rankine's equation (2), page 312.

It is well to observe that $d\,v$ in the second term is involved in a different operation from that in the third term; the latter being a part of the actual operation in passing from a to c, *Fig. 3*, while the former is a purely ideal one for determining a value for the variable specific heat at v. In order to reduce the second term, the equation of the gas must be known. Thus, if it be

$$p = R\frac{\tau}{v} - \frac{a}{\tau\,t^2}$$

as it is for carbonic acid gas, then considering v as constant during the differentiation,

$$\frac{d^2 p}{d\,\tau^2} = -\frac{2\,a}{\tau^3\,v^2},$$

then integrating, considering τ as constant, since the integration is along the isothermal $b\,e$,

$$\int \frac{d^2 p}{d\,\tau^2}\,d\,v = -\frac{2\,a}{\tau^3}\int_{\infty}^{v} \frac{d\,v}{v^2} = \frac{2\,a}{\tau^3\,v},$$

and the second term of equation (2) becomes, for this particular gas,

$$\left(\frac{2\,a}{\tau^3\,v}\right) d\,\tau$$

The value of the expression $\frac{2\,a}{\tau^3\,v}$ is so small for known gases,

compared with C_v that it may generally be omitted. Thus, for carbonic acid gas

$$a = 3{\cdot}42 \times 17264 \times 8{\cdot}1572,$$

and if the temperature be that of melting ice, 493°·2 F., at the pressure of one atmosphere, then

$$\frac{2\,a}{\tau^2\,v} = \frac{2 \times 3{\cdot}42 \times 17264 \times 8{\cdot}1572}{(493{\cdot}2)^2 \times 8{\cdot}1572} = 0{\cdot}42 +,$$

while C_v is about 132. Since it is impossible to find the value of C_v with perfect accuracy, it is apparent that 0·42 may be omitted without sensible error, since it falls within the limits of the errors of observation.

The integral of equation (2) between the limits belonging to the conditions of the problem, would give the heat absorbed. But it is impossible to find the general integral; it may, however, be found in the following cases:

(1.) When the gas is perfect and the equation of the path described is known.

(2.) When the gas is imperfect, its equation being known, and the expansion isothermal.

(3.) When the pressure and temperature are constant during expansion.

CASE I.

For a perfect gas we have

$$p\,v = R\,\tau;$$

$$\therefore \left(\frac{d\,p}{d\,\tau}\right)_v = \frac{R}{v},$$

$$\left(\frac{d^2\,p}{d\,\tau^2}\right)_v = o,$$

which, substituted in equation (2), gives

$$d\,H = C_v\,d\,\tau + R\,\frac{\tau}{v}\,d\,v$$

$$= C_v\,d\,\tau + p\,d\,v$$

which, integrated, gives

$$H_{a,b} = C_v\,(\tau_2 - \tau_1) + \int_{v_1}^{v_2} p\,d\,v. \qquad (3)$$

The several terms of this equation may be illustrated by means

FIG. 5.

of *Fig. 5*. Let A and B be respectively the initial and terminal states of the gas, the line $A\,B$ being the path of the gas in expanding from v_1 to v_2. The last term, or

$$\int_{v_1}^{v_2} p\,dv$$

is the external work done, and equals $v_1\,A\,B\,v_2$, and since the gas is perfect, the heat absorbed will be represented by the same area. Through A draw the isothermal $A\,C$, and through A, C, B, respectively, the adiabatics; then, according to the second law, the heat absorbed, while generating the path $A\,C$, will be

$$\text{area } m_1\,A\,C\,m_2 = v_1\,A\,C\,v_2.$$

The area $A\,C\,B$ represents at the same time a portion of the external work and a corresponding equal quantity of heat; hence

$$m_1\,A\,B\,C\,m_2 = v_1\,A\,B\,v_2.$$

The term

$$C_v\,(\tau_2 - \tau_1)$$

will be represented by the area $m_3\,C\,B\,m_3$, τ_2 being the temperature of the substance at the state B, and τ_1 at the states A and C; hence the second member will be represented by the area $m_1\,A\,B\,m_3$, which represents the heat absorbed in passing from the state A to the state B, and indicated by $H_{a,b}$.

Let the equation of the path of $A\,B$ be known, or

$$p = \varphi\,(v),$$

in which case the area $v_1\,A\,B\,v_2$ may be found. To be more

specific, let the path be a straight line, whose equation is

$$p = a + b\,v,$$

then

$$\int p\,dv = \int_{v_1}^{v_2} (a + b\,v)\,dv,$$

which is easily reduced.

CASE II.

When the temperature is constant, we have $d\tau = o$, and equation (2) becomes

$$d\,H = \tau \frac{dp}{d\tau}\,dv.$$

Let the equation of the gas be

$$p\,v = R\tau - \frac{a}{\tau\,v}, \tag{4}$$

then

$$\tau\left(\frac{dp}{d\tau}\right)_v = R\,\frac{\tau}{v} + \frac{a}{\tau\,v^2} \tag{5}$$

$$= p + \frac{2\,a}{\tau\,v^2}; \tag{6}$$

$$\therefore d\,H = \left(p + \frac{2\,a}{\tau\,v^2}\right) dv;$$

hence for an isothermal expansion

$$H_{a,b} = \int_{v_1}^{v_2} p\,dv - \frac{2\,a}{\tau}\left(\frac{1}{v_2} - \frac{1}{v_1}\right)$$

$$= \int_{v_1}^{v_2} p\,dv + \frac{2\,a}{\tau}\left(\frac{1}{v_1} - \frac{1}{v_2}\right), \tag{7}$$

the last term of which is the internal work done during the expansion, and may be represented by *area A a b B*, *Fig. 6.*

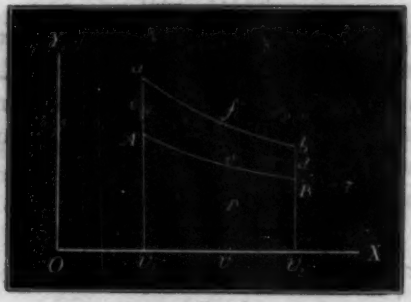


FIG. 6.

The external work will be

$$v_1 A B v_2 = \int p\,dv = \int_{v_1}^{v_2} \left(R\frac{\tau}{v} - \frac{a}{\tau v^2} \right) dv$$

$$= R\tau \log \frac{v_2}{v_1} - \frac{a}{\tau}\left(\frac{1}{v_1} - \frac{1}{v_2} \right)$$

which, substituted in (7), gives

$$H_{a,b} = R\tau \log \frac{v_2}{v_1} + \frac{a}{\tau}\left(\frac{1}{v_1} - \frac{1}{v_2} \right)$$

We note here an interesting fact in regard to the actual and the virtual pressures. Let $A\,B$ be the isothermal of the gas whose equation is (4) above. If now it were possible to remove the imperfection, all other qualities remaining the same, the ordinate p would gradually increase, and when a becomes zero, we would have the equation of a perfect gas, or,

$$p = R\frac{\tau}{v}.$$

Let $c\,d$ be the isothermal in this case. Or, to put it another way, assume $a = o$, and find the corresponding isothermal $c\,d$; then, from equation (4),

$$A\,c = \frac{a}{\tau v^2}.$$

But the virtual ordinate doing the internal work, is, from equation (6),

$$\frac{2\,a}{\tau v^2} = A\,a,$$

from which it appears that

$$a\,c = c\,A.$$

As a physical explanation of the manner of producing this result, conceive that the gas is perfect, then at the volume v_1 the pressure will be $c\,v_1$. Now conceive that the gas undergoes such a change, so as to become imperfect; not only would the pressure fall, as shown by equation (4), but because internal work is being done, the temperature would fall, and hence to maintain the initial temperature, the substance must absorb heat, to represent which the *virtual* pressure must be increased, so that while A falls below c, a will rise above. The distance $A\,c$ will equal $c\,a$ only when the equation of the gas is of the form of equation (4).

CASE III.

When p and τ are both constant, equation (2) becomes

$$H = \tau \frac{dp}{d\tau} \int_{v_1}^{v_2} dv$$

$$= \tau \frac{dp}{d\tau} (v_2 - v_1), \qquad (8)$$

which is applicable to cases of fusion and of evaporation.

Returning now to the general equation (2), we observe that in the third term, the factor $\tau \frac{dp}{d\tau}$ may, in all cases, be considered as a *virtual pressure*, such that being multiplied by dv, gives an element of the work, both external and internal, for the expansion dv. Subtracting the external work, $p\,dv$, gives the internal work due to expansion; hence adding and subtracting $p\,dv$, equation (2) becomes

$$dH = C_v d\tau + \tau \int_{v_1}^{v_2} \frac{d^2p}{d\tau^2} dv . d\tau + \left(\tau \frac{dp}{d\tau} - p\right) dv + p\,dv$$

or, integrating,

$$H_{a,b} - \int_{v_1}^{v_2} p\,dv = C_v(\tau_b - \tau_a) + \int \left[\tau \int_{v_1}^{v} \frac{d^2p}{d\tau^2} dv . d\tau + \left(\tau \frac{dp}{d\tau} - p\right) dv\right], \qquad (9)$$

the last term of which represents the internal work done due to changes of temperature and volume. *The resultant internal work is dependent only upon the initial and final states of the gas and not upon the intermediate path.*

To illustrate this point, suppose that in passing from A to B, *Fig. 5*, the temperature at some part of the path were made to exceed that at B by 50°, more internal work would be done in raising the temperature this amount, than if it had not been made to exceed that of B; but in the remainder of the path, in bringing the temperature down from the 50° above B to that of B, the excess of internal work that had been performed will be undone, and the final result upon reaching B will be the same as if the temperature had in no part of the path exceeded that of B.

Similarly, the resultant internal work done by expansion will be the same, whether the expansion increases directly from v_1 to v_2, or whether there be expansions and compressions. Thus suppose that some part of the path in passing from A to B should be five feet to the right of the $v_2 B$, more internal work would be done in producing this five feet of expansion than if the expansion were limited to v_2, but in reaching the state B, there must be a compression of these five feet, so that the previous extra internal work will be undone, the final result being the same as if the path did not cross the ordinate $v_2 B$. The same reasoning would apply if the path passed to the left of $v_1 A$. The external work, $v_1 A B v_2$, is dependent upon the path $A B$. This being the case, we may choose the path along which we may conceive the substance to be worked in order to determine the internal work, which path may have no relation to the one actually described in doing external work; and such a path may be chosen as will favor the algebraic analysis. In *Fig. 5*, conceive that the fluid is expanded along the isothermal $A C$ from v_1 to v_2, thence at the constant volume v_2 the pressure is raised from C to B; then will the internal work be

$$\text{from } A \text{ to } C, \int_{v_1}^{v_2} \left(\tau \frac{dp}{d\tau} - p \right) dv, \qquad (10)$$

in which τ is constant, and is represented by $A a c C$, *Fig. 5*, and

$$\text{from } C \text{ to } B, \int_{\tau_c}^{\tau_1} \int_{v_2}^{v_2} \tau \frac{d^2 p}{d\tau^2} d\tau \, dv, \qquad (11)$$

in which v is constant in determining $\frac{d^2 p}{d\tau^2}$ from the equation of the gas, but variable in reference to the integral, and τ variable throughout the operation. The last expression is not written in the order given by the author, but is made to conform to modern forms involving successive integrations; according to which all the terms involving v are integrated between proper limits, after which the remaining integral is performed. Since v and τ are entirely independent of each other, the integrations in this case may be performed in reverse order, with the same final result. The fact that τ is treated as constant in the first integration, makes it proper to place it before the integral sign, as in equation (9), but

it is unnecessary to state that it is equally correct to place it after the integral sign as in (11), both forms producing the same final value. The conditions of the solution make $\tau_a = \tau_c$.

As a special example illustrating the use of equations (10) and (11), let the equation of the gas be as given in equation (4), then equation (6), substituted in (10), gives—

$$\int_{v_1}^{v_2} \frac{2a}{\tau_a v^2} dv = \frac{2a}{\tau_a}\left(\frac{1}{v_1} - \frac{1}{v_2}\right), \tag{12}$$

and from (4) find

$$\tau \frac{d^2 p}{d\tau^2} = \frac{2a}{\tau^2 v^2},$$

which in (11) gives

$$\int_{\tau_c}^{\tau_b} \int_{\infty}^{v_2} \frac{2a}{\tau^2 v^2} d\tau dv = -\frac{2a}{v_2} \int_{\tau_c}^{\tau_b} \frac{d\tau}{\tau^2} = \frac{2a}{v_2}\left(\frac{1}{\tau_c} - \frac{1}{\tau_b}\right) \tag{13}$$

The entire internal work done in passing from state A to state B will be the sum of the values in equations (12) and (13), and is represented by ΔS, in the *Steam Engine*, page 304, and in some other places simply by S. Hence, in this case,

$$S = 2a\left[\frac{1}{\tau_a}\left(\frac{1}{v_1} - \frac{1}{v_2}\right) + \frac{1}{v_2}\left(\frac{1}{\tau_c} - \frac{1}{\tau_b}\right)\right] = 2a\left[\frac{1}{\tau_a v_1} - \frac{1}{\tau_b v_2}\right] \tag{14}$$

which admits of a numerical value when a and the initial and final limits are known.

The author, in the article under consideration, uses S_a and S_b for the values of the potential energy necessary to overcome molecular forces in expanding unity of weight of a substance from the states A and B, respectively, to that of a perfect gas; the last clause of which simply means that the gas is expanded indefinitely.

We may conceive the fluid worked along other paths than those just indicated in *Fig. 5;* for instance, it may be worked along the adiabatic $A m_1$ indefinitely, becoming asymptotic with the adiabatic through B, and then compressed along $m_1 B$ to B, in which case, we have

$$S_a = \int_{v_1}^{\infty} \left(\tau \frac{dp}{d\tau} - p\right) dv,$$

$$S_b = \int_{v_0}^{\infty} \left(\tau \frac{dp}{d\tau} - p\right) dv,$$

as shown in *Fig. 7*, in which τ, p and v are all variable, but the

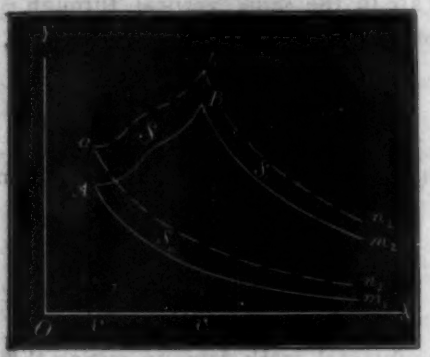


FIG. 7.

integration cannot be performed under these conditions, even if the equation of the adiabatic were known, for there would be two variables after elimination, one dependent upon the other.

Since all isothermals of the same gas are mutually asymptotic, one may pass from A outward on the isothermal τ_a, indefinitely, and back to B on the isothermal τ_b. In this case, we have

$$S_a = \int_{v_1}^{\infty} \left(\tau_a \frac{dp}{d\tau} - p\right) dv \qquad (15)$$

$$S_b = \int_{v_2}^{\infty} \left(\tau_b \frac{dp}{d\tau} - p\right) dv \qquad (16)$$

which may be integrated, since τ will be constant. In passing from A to B, thence, indefinitely, along the isothermal τ_b, and finally back to A along the isothermal τ_a, the sum of the internal works will be zero, or

$$S + S_b - S_a = 0;$$
$$\therefore S = S_a - S_b \qquad (17)$$

In passing from state A to state B, the total heat absorbed will equal the total work done, internal and external, added to the increased energy of the substance; hence, or by equation (9),

$$H = \int p\, dv + S + C_v(\tau_b - \tau_a),$$

or, in the form given by the author, after substituting from (17),

$$H - \int p\,dv = (C_v\,\tau - S)_b - (C_v\,\tau - S)_a \qquad (18)$$

which is the author's equation (2), page 313

If A and B are in the same vertical through v_2, no external work will be done in passing from state A to state B, hence

$$\int p\,dv = 0,$$

and

$$H = (C_v\,\tau_b - S_b) - (C_v\,\tau_a - S_a).$$

If A be at the foot of the perpendicular $B\,v_2$, then

$$\tau_a = 0,$$

and

$$\begin{aligned} H &= C_v\,\tau_b - S_b + S_a \\ &= C_v\,\tau_b + S \end{aligned} \qquad (19)$$

in which S is the internal work done in raising the temperature from zero to τ_b.

If the gas were perfect, the entire energy, $C_v\,\tau$, would be expended in doing external work by an indefinite adiabatic expansion, a fact easily verified by showing directly that the area $m_1\,A\,v_1\,X$, *Fig. 5*, indefinitely extended, equals $C_v\,\tau_a$; and the entire area under the adiabatic represents the *intrinsic* energy of a perfect gas. But if the gas be imperfect, a part of the energy possessed by the substance will be expended in overcoming its own molecular attractions during expansion, so that the external work which it can do is less by the amount of internal work so done; hence, in the state B, the *intrinsic* energy, or the external work which it can do by virtue of the energy it possesses, by an indefinite expansion, will be

$$C_v\,\tau_b - S_b,$$

and similarly for the state A. This is also the area under the adiabatic of the imperfect gas, but the area is less for the same temperature.

To ascertain if equations (15), (16), (17), will give the same result as (12) and (13) for the particular gas here considered, we find in the same manner as in equation (12), which is the same as (15) when $v_2 = \infty$,

$$S_a = \frac{2\,a}{\tau_a\,v_1};$$

similarly,

$$S_b = \frac{2a}{\tau_b v_2};$$

which, in (17), give

$$S = 2a\left(\frac{1}{\tau_a v_1} - \frac{1}{\tau_b v_2}\right)$$

which is the same as (14); hence, the two processes give the same results in this case.

In the same manner, the two processes may be verified for the more general equation of imperfect fluids, which, as given by Rankine, and verified to some extent by Regnault, is

$$\frac{pv}{p_0 v_0} = \frac{\tau}{\tau_0} - a_0 - \frac{a_1}{\tau v} - \frac{a_2}{\tau^2 v} - etc.,$$

in which a_0, a_1, a_2, are functions of the density, and assuming them to be inverse functions of the specific volume, and multiplying through by $p_0 v_0$, it may be written,

$$p = R\frac{\tau}{v} - \frac{A_0}{v} - \frac{A_1}{\tau v^2} - \frac{A_2}{\tau^2 v^2} - etc.$$

From this find

$$\int_{v_1}^{v_2}\left(\tau_a \frac{dp}{d\tau} - p\right)dv = \left(A_0 + \frac{2A_1}{\tau_a} + \frac{3A_2}{\tau_a^2} + etc.\right)\left(\frac{1}{v_1} - \frac{1}{v_2}\right),$$

$$\int_{\tau_a}^{\tau_b}\int_{\infty}^{v_2}\frac{d^2p}{d\tau^2}\tau\, d\tau\, dv = \frac{2A_1}{v_2}\left(\frac{1}{\tau_b} - \frac{1}{\tau_b}\right) + \frac{3A_2}{v_2}\left(\frac{1}{\tau_a^2} - \frac{1}{\tau_b^2}\right) + etc.,$$

the sum of which is

$$S = \left(A_0 + \frac{2A_1}{\tau_a} + \frac{3A_2}{\tau_a^2} + etc.\right)\frac{1}{v_1} - \left(A_0 + \frac{2A_1}{\tau_b} + \frac{3A_2}{\tau_b^2} + etc.\right)\frac{1}{v_2}. \qquad (20)$$

Equations (15) and (16) give

$$S_a = \left(A_0 + \frac{2A_1}{\tau_a} + \frac{3A_2}{\tau_a^2} + etc.\right)\frac{1}{v_1}$$

$$S_b = \left(A_0 + \frac{2A_1}{\tau_b} + \frac{3A_2}{\tau_b^2} + etc.\right)\frac{1}{v_2},$$

which in (17) give precisely the same value for S as just found in equation (20). No further verification of the analysis is needed.

If, in (20),

$$A_0 = 0,\ A_1 = a,\ A_2 = 0,$$

it becomes

$$S = 2a\left(\frac{1}{\tau_a v_1} - \frac{1}{\tau_b v_2}\right)$$

which is the same as (14). In this, if

$$\tau_a v_1 = \tau_b v_2,$$

the internal work for this gas in working from state A to state B will be zero. If external work be done in this case, we have

$$v_2 > v_1;$$
$$\therefore \tau_b < \tau_a$$

and if the final temperature exceed the initial, work must have been done upon the gas since v_2 will be less than v_1; for

$$v_2 = v_1 \frac{\tau_a}{\tau_b},$$

the result being produced by compression during the absorption of heat.

Recognizing the fact that the matter treated in the pages of the *Steam Engine*, here considered, is so greatly condensed as to make it exceedingly difficult for the student to surmount the difficulties encountered, we have considered it better to err, if at all, on the side of unnecessarily minute explanations, rather than assume an amount of knowledge of the subject by the reader.

ALUMINIUM AND ITS ALLOYS; WITH EXPERIMENTAL INVESTIGATIONS.

By EDWARD D. SELF, Stevens Institute of Technology.*

(*Continued from Vol. CXXIII, page 226.*)

ALUMINIUM ALLOYS.

The alloys of aluminium form a subject that will doubtless be of the greatest interest to the engineer of the future. They are exceedingly numerous, and the range of proportions of the ingredients to produce useful alloys is very wide. In a general way, aluminium may be said to improve the qualities of every metal to which it is added in small quantities. It increases the strength and lustre of the softer metals and renders others much less liable to corrosion. It alloys with nearly all the useful, as well as precious, metals. When alloyed with iron, it cannot be entirely separated in a metallic form. Iron containing over seven or eight per cent. of aluminium becomes brittle and crystallizes in long needles.

Alloyed with a small per cent. of silver, it loses much of its malleability; but with five per cent. of silver it can be worked well, and takes a more beautiful polish than the pure metal. With three per cent. of silver, it is very suitable for philosophical instruments, being harder and whiter than the pure metal, and is not tarnished even by sulphuretted hydrogen.

With small amounts of silver, it appears very suitable for scale-beams, and is now frequently used for this purpose. The alloy containing five per cent. of silver has often been suggested for coin of small denominations, as it is hard, bright and retains its lustre in handling.

With tin, several characteristic alloys of no importance are formed. They are, in general, hard, brittle and slightly malleable.

The most interesting alloy with zinc contains three per cent. of aluminium. It is harder than either metal, and the brightest of all the alloys we are considering.

* Graduation Thesis, 1886.

The presence of bismuth, as might be expected, produces brittleness.

Ninety-seven per cent. of gold and three per cent. of aluminium give a more beautiful color to the gold, and yet the latter metal does not lose in ductility or malleability.

It can be seen from even the brief sketch of alloys given, that the introduction of small quantities of foreign metals into aluminium improves its brilliancy and hardness without very greatly injuring its other properties; while the properties of other metals are almost invariably improved by the addition of small amounts of aluminium.

The most important alloys, and next to be considered, are the alloys with copper. These form a striking series, of which the alloy of ten per cent. of aluminium and ninety per cent. of copper is the most prominent.

This compound was discovered as early as 1856, by John Percy, and its wonderful properties were soon partly recognized, and it received the name of aluminium-bronze, which has subsequently been extended to other compositions containing different per cents. of copper.

Early mention is made of the excellent qualities of this bronze in the *Comptes Rendus*, where its application for rollers is stated to have given much better results than ordinary bronze.

It was never made in appreciable quantities until about 1867. In observing the different alloys with copper, we notice a gradual change in properties as the copper is increased in amount. Aluminium can contain ten per cent. copper, and still retain most of its malleability. Exceeding ten per cent., however, it becomes brittle, but retains its white color up to nearly eighty per cent. The eighty-five per cent. alloy is brittle, but has a yellow color, and it is probable that the change in tint occurs at or about eighty-two per cent.

The ten per cent. aluminium-bronze possesses a deep golden color and has a specific gravity of 7·7. It can be forged and shaped at a red heat, and hammered until cold without cracking.

When it is made by a simple mixing of ingredients, it is brittle and does not acquire its best qualities until after having been cast several times. After three or four meltings, it reaches a maximum; at which point it may be melted several times without sensible

change. As it cools rapidly, large castings require some care to prevent cracking, so numerous runners and a large feeding-head should be employed. The ten per cent. bronze fuses at about the temperature of brass containing thirty-three per cent. zinc; and the five per cent. melts at a somewhat higher temperature. The former should be poured as cool as possible to produce sharp castings, and should be kept covered with charcoal up to the moment of pouring. Considerable care must be taken in the preparation of "risers," so that the metal will free itself of impurities. The metal can conveniently be freed from slag, or other impurity, when pouring into the mould, by the following method: A supplementary pot, or crucible, with a hole in its bottom, is secured over the pouring-gate of the mould. This hole is first plugged up by a carbon or iron rod heated to redness, and the pot is filled with the melted metal before the plug is withdrawn. This allows the oxide and slag to rise to the surface, and admits only pure metal to the mould. It also prevents the oxidation that a stream of metal would suffer in pouring through the air to the "pouring-gate," as is often practised.

The shrinkage of ten per cent. bronze in casting is about fifty per cent. more than ordinary brass.

Aluminium-bronze forges similarly to the best Swedish iron, but at a much lower temperature. It works best at a cherry red; if this is much exceeded, the metal becomes "hot short," and is easily crushed. The temperature for rolling is a bright red heat, and it is a curious fact that if the metal were forged at the temperature it is rolled, it would be smashed to pieces. If the temperature in the ordinary muffle in which it is heated be allowed to rise too high, the bronze will frequently fall apart by its own weight. When in the rolls, it acts very much like yellow Muntz metal. As it loses its heat much more rapidly than copper or iron, it has to be annealed frequently between rollings.

The following examples of rolling were given the author by the Cowles Electric Smelting and Aluminium Company: A billet of ten per cent. bronze, about 18″ x 1¼″ x 1¼″, was rolled in a Belgian train to quarter-inch rod, at one annealing The five per cent. bronze is harder to roll hot than the ten per cent., but in cold-rolling just the reverse is true; a piece of five per cent. sheeting, eight inches wide, has been reduced eight gauge numbers

when rolled cold, at one annealing; while a ten per cent. sheet could not be reduced more than half that number. The billets for rolling can best be prepared by casting in iron moulds previously rubbed with a mixture of plumbago, pipe-clay and lard-oil. The metal chills very quickly, and very smooth castings can be produced, the smoothness depending considerably on the speed of pouring. With care, the five and ten per cent. bronzes can be easily drawn into wire. It is preferable, however, to first roll the five per cent. to quarter-inch rods and the ten per cent. to a less diameter, and anneal them. The metal thus prepared is much tougher and less liable to break in drawing. The dies must be very hard, or the ordinary wire, and especially the higher grades, is apt to cut them. The speed of the draw-blocks must be less than for iron, brass, copper, german-silver, or soft steel, and the reduction must be more gradually effected.

Numerous tests have been made of the tenacity of the aluminium-bronzes in general, and the following are some of the results given by different experimenters and writers:

Rankine (*Ship-building*), ...	73,000 lbs. per square inch.
Anderson, ...	75,600 " " "
Seaton (*Marine Engineering*),	64,000 to 80,000 " " "

The following results were obtained at the South Boston Iron Works, with pieces of the Cowles Company's alloys, February, 1886:

Name.	*Tensile Strength.*	*Elastic Lim.*	*Elongation Per Cent.*
10 per cent. Al B.,	91,463 lbs. per square inch,	. . .	1½
10 " "	92,441 " "	59,815	2½
10 " "	96,434 " "	85,034	1
9 " "	77,062 " "	51,774	9
9 " "	71,698 " "	44,025	9
8½ " "	72,019 " "	. . .	28½
7½ " "	60,716 " "	45,537	6

The length of above pieces between shoulders was six inches; diameter not given.

The following tests were made at the Washington Navy Yard, of pieces very nearly half an inch in diameter, and two inches between shoulders.

Name.	*Tensile Strength.*	*Elastic Lim.*	*Elongation.*
10 per cent. Al B.	114,514 lbs. per sq. in.	. . .	0·45
10 " "	95,366 " "	69,749	·05
10 " "	109,823 " "	79,894	·05

The following results were obtained with specimens ·564 inch diameter, and four inches between shoulders, tested at the Watertown Arsenal.

Name.	*Tensile Strength.*	*Elastic Lim.*	*Elongation.*
9 per cent., Al B,	71,800	. . .	8·25
8 " "	57,920	. . .	12·25

A number of remarkable and useful alloys are made by mixing aluminium-bronzes with nickel in various proportions. These compositions are said to be very ductile, and to have a tenacity of from 75,000 to over 100,000 pounds per square inch, with about thirty per cent elongation. Tests made by Kirkaldy on alloys of a similar nature made by the Webster Crown Metal Company, England, give results ranging from 82,000 to a little over 100,000.

The addition of a few per cent. of aluminium to common brass, greatly increases its tenacity and resistance to corrosion. Alloys containing copper, zinc and Al between the following limits:

Cu, ...	67 to 71 per cent,
Zn, ...	27½ " 30 " "
Al, ...	1¼ " 3 " "

and combined in different proportions, give tenacities from a little above 30,000 to over 65,000 pounds per square inch. Alloys with much less copper and more zinc—55·8 to 57 per cent. copper, and 42 to 43 per cent. zinc—approach nearer 70,000 pounds, and a specimen composed of

67·4 per cent. Cu,
26·8 " " Zn,
5·8 " " Al

broke at over 95,000 pounds tenacity per square inch.

An incident that occurred in the Imperial postage stamp manufactory, Paris, may be here cited as illustrating some of the peculiar properties of aluminium-bronze. Great trouble was experienced to procure a suitable die-plate to place beneath the needles of a machine used for perforating sheets of postage stamps. At every blow, the needles passed through the holes in the die-plate, and as there were 300 needles making rapid strokes, about 180,000,000 holes were made per day! With this usage, brass plates wore out in a day, and even steel plates were speedily destroyed. A plate of bronze being substituted, lasted for months without renewal.

The experiments of Strange showed that Al bronze possessed forty times the stiffness of ordinary brass and eight times that of ordinary bronze.

A suggestive statement is made by Guettier, to the effect that the resistance to traction of this bronze is 5·328 kilograms per square centimetre, whereas that of common ordnance bronze (Woolwich) is but 2·555 kilograms per square centimetre.

It is evident from the striking properties of the bronzes and alloys just described, that their applications would be almost limitless, could they at present compete with brass in price. They can not only be used wherever brass is employed, but can very often be made to take the place of iron or steel. Passing over the multitude of applications to articles of every-day use, the bronze has a tenacity and elongation that would easily fill the required standards for the wrought steel used by the British and German governments for cannon—which are about 70,000 pounds tensile strength and fifteen per cent. elongation. The guns referred to could be made of equal strength, in much less time and with less cost if the ten per cent. bronze were employed.

An alloy, made by the Webster Company, has been tried for propeller-blades, on a vessel whose bottom was subjected to the destructive influences of the waters of tropical rivers and oceans; the blades were in use for some time, and no appreciable results from galvanic action or corrosion were apparent.

For anti-frictional purposes, the alloys of aluminium seem well suited, and a peculiar compound, made by the Webster Company, has been used for steamship eccentric-straps, and received many encomiums from practical men. The Cowles bronzes have also run successfully for high speed bearings on dynamos.

For various household uses, the different alloys seem to be unexcelled. The golden color of the five per cent. bronze makes it very suitable for plumbers' and similar fittings, and its resistance to corrosion is greater than that of the materials generally used. For cooking utensils and even table-ware, these alloys are unsurpassed in color and durability. The color of gold and silver can be perfectly imitated without the offensiveness resulting from plating brass. Samples of table-ware made of Webster "white metal" were shown the writer, and appeared equal to silver in color and lustre, even after several months of indifferent treatment and exposure to New York City air.

There is at present one great drawback to the use of these bronzes for small manufactured articles—the difficulty of soldering. There is now no cheap and simple method of brazing Al bronzes, and they cannot be welded.

Pieces, however, can be united by the following jewellers' solders:

Hard solder for ten per cent. bronze, . . .	Gold,	88·88 per cent.
	Silver,	4·68 "
	Copper,	6·44 "
		100·00
Middling solder for ten per cent. bronze, . .	Gold,	54·40 per cent.
	Silver,	27·60 "
	Copper,	18·00 "
		100·00

Soft solder for Al bronzes in general is made by adding brass to the ingredients already given, thus:

Brass, ...	14·30 per cent.
Gold, ...	14·30 "
Silver, ...	57·10 "
Copper, ...	14·30 "
	100·00

The brass is composed of copper, seventy per cent., and tin, thirty per cent.

MANUFACTURE OF ALUMINIUM-BRONZES.

These bronzes have frequently been made in amounts large enough for testing, by melting together the correct proportions of copper and aluminium, but such a method will never be a commercial success while the ingredients have their present prices. The most economical way seems to be to make the alloys themselves as a first product, and reduce the alumina in the presence of copper.

The process of H. Niewerth, of Hanover, is briefly this: Ferro-silicium and fluoride of aluminium are mixed together in suitable proportions, and submitted to a red heat, which decomposes the bodies into volatile silicon fluoride, iron and aluminium, the latter forming an alloy with the iron. This alloy is then melted with copper, which, having a greater affinity for aluminium than has the iron, unites with the former to produce the bronze. After the mass has cooled and been broken, the iron can be separated without much difficulty.

Cryolite, or Al chloride, can be used in place of the fluoride. With the chloride, silicon chloride is produced.

We will now consider a new method of producing Al bronze, already briefly mentioned, and observe it in all its details, through the courtesy of its present manufacturers, who have kindly given the writer many interesting and instructive data concerning their process.

The furnace used by the Cowles Electric Smelting and Aluminium Company consists of a fire-brick box, 1 foot wide, 5 feet long and 15 inches deep. From opposite ends, enter two immense electrodes, that are really electric-light carbons, 3 inches in diameter and 30 inches long. These are partly contained in pipes that, in turn, pass through stuffing-boxes in the ends, to exclude the air, and, at the same time, admit of adjusting the electrodes.

To protect the walls of the furnace from the intense heat, it is lined with finely-powdered charcoal, which, having been first washed in a solution of lime-water, retains its non-conductivity even after the particles have been partially converted into graphite by heat.

The bottom of the furnace is now lined to a depth of two or three inches with this fine, prepared charcoal, and, by means of a sheet-iron gauge, the walls of the furnace are covered with charcoal to the thickness of two inches.

The charge, consisting of about twenty-five pounds of corundum, twelve pounds charcoal and carbon, and fifty pounds of granulated copper, is placed about the electrodes to within a foot of each end of the furnace. A layer of coarsely-broken charcoal is now spread over the charge, and the sheet-iron gauge withdrawn. The coarse charcoal on top allows the escape of carbonic-oxide gas formed during the process. An iron cover, lined with fire-brick, is luted on to prevent the entrance of air.

The charge is now prepared, and the furnace ready to be connected with an immense Brush dynamo—capable of producing ninety horse-power of electrical energy. In the circuit between the dynamo and furnace, is an ammeter, designed to register from fifty to 20,000 ampères of current, which is controlled by a large resistance-box, as the ends of the electrodes may at first be too close together to make it safe to start the dynamo. By watching the ammeter and moving the electrodes, the resistance-box can be

taken gradually out of circuit, without producing a "short circuit" at the beginning of the operation. In about ten minutes, after the copper about the electrodes has become melted, the latter are slowly moved apart until the current becomes steady. It is now increased to about 1,300 ampères and fifty volts. Carbonic oxide begins to escape from the orifices made in the top, and burns in two white plumes of flame. By regulating the distance between the electrodes, the current is kept constant for about five hours, and all parts of the charge are brought into the reducing zone.

When the operation is completed, a resistance is placed in the box and the current is switched into another furnace charged in a similar manner. The product is an alloy of copper containing fifteen to thirty per cent. of aluminium, and having a beautiful silver color when broken. The copper performs no part in the reduction, but is employed to absorb the aluminium, which would otherwise be converted into a carbide.

This alloy is now melted in an ordinary crucible-furnace and run into ingots, which, after being analyzed, are re-melted and sufficient copper added to produce the standard bronzes.

Two runs from the furnace described will produce about 100 pounds containing about fifteen per cent. of aluminium. From this data, it is estimated that pure metal can be produced, in its alloys, at about forty cents per pound, with a large plant at present in construction.

It is evident that a large electrical smelting plant need not be restricted to the production of aluminium and its bronzes, but also boron, sodium potassium, calcium, magnesium, chromium and titanium can be reduced by varying the details of operation.

The production of pure metallic aluminium still lacks some features necessary for its economical manufacture; but a complete solution of the problems of electric smelting will doubtless enable the metal to be placed on the market at a price that will insure for it an almost universal application.

EXPERIMENTAL INVESTIGATIONS.

The following is a description of experiments made by the writer, with specimens of aluminium-bronzes kindly furnished by the Cowles Electric Smelting and Aluminium Company. As the time devoted to this part of the work was necessarily curtailed,

owing to time spent on previous chapters, the writer does not regard his work as conclusive as to details, but believes that enough is here shown to point out the directions in which experimental investigations can be carried in the future that may be of interest and value. Such experiments may show that in certain applications the bronzes excel to a degree little thought of.

The exterior of the ingot used by the writer was a frosted gold color—the interior was of a brighter color, similar to that of new gold coins. After fastening to a planer-bed, test pieces were cut out for tension and torsion. The surface was naturally found to be harder than the interior, but was covered by a very thin skin. The centre of the pig on the upper surface showed what appeared to be bad cracks due to cooling; but on moving this surface the flaws were found to be surprisingly superficial. The bronze cut with great ease on the planer, the chips separating easily and quickly In this respect it works better than brass of equal hardness, and the tool leaves a surface of remarkable polish and lustre.

An illustration of toughness was shown when, after the "parting tool" had run almost to its depth, it became necessary to break-off the test piece which was held to the main piece of metal by a web about 9″ x $\frac{1}{16}$″ x $\frac{1}{8}$″. As the piece showed too much ductility to be conveniently removed by using a cold chisel, a wrench was applied, and it was only after repeated efforts in bending backwards and forwards that the piece was finally removed. This piece was then cut in two, and standard torsion pieces were turned with square shoulders and a cylindrical portion $\frac{5}{8}$ inch diameter and 1 inch long. In doing this, it was found the metal cut dry on the lathe with great ease and smoothness. The speed of running being equal or higher than usually employed in turning brass, the chips came off very rapidly and exhibited no tenacity, as the feed at the same time was large. With a drill in good condition, a three-fourths inch hole can easily be bored on a small power lathe, care being taken to keep the hole clean and avoid unnecessary heating. Under the file, the metal worked similarly to brass, but does not clog to any serious extent. It is, however, much harder to cut with a "hack saw" than common brass.

(*To be continued.*)

TURBINES.

By Irving P. Church, C. E.,
Assistant Professor Civil Engineering, Cornell University.

In his introduction to Mr. Woodbridge's thesis on "Turbines," in the recent November and December numbers of this journal, Prof. Wood seems to imply that the former's solution, as based "upon the resolution of the pressures of elementary volumes and their moments," is the first employment of such a method.

Without the slightest desire to detract from the credit due to Mr. Woodbridge's achievements, it is perhaps permissible, in justice to the present writer, to state that this method of solution was developed by him several years ago and has been used in his classes at this institution ever since; with such variations in the details from Mr. Woodbridge's, however, as to render its publication in this journal of some interest to students of applied mechanics. It would have been published as a whole long before, had not the writer supposed that most teachers of applied mechanics would probably be led to discover it for themselves, in the effort to smooth the pathway of their pupils. Some portions have already appeared in periodicals, as will be mentioned presently, and these will not be repeated here, except as it may be desirable to present clearer and more direct proofs than those previously given.

The theory of the friction-less turbine consists mainly in the establishing of the first six equations of the article by the writer in this journal for May, 1884, (pp. 333 and 334), with the proviso that at whatever *uniform* angular velocity, ω, the wheel be run, the vane-tangent at entrance of wheel-channel is to coincide in direction with the relative velocity of the water issuing from the guides, and also that all channels are filled.

The question of the proper speed for maximum efficiency will not be entered upon here; Weisbach's treatment of that point being simple and clear, and exact enough for practical purposes.

Of these six equations, (3), (4) and (5), are too simple to need explanation here; (2) is Bernoulli's theorem for steady flow in a *fixed* pipe or channel, proved in all text-books on hydraulics, and dealing with the absolute velocity at entrance; (6) may be called

Bernoulli's theorem for a *rotating* pipe (in horizontal plane) and deals with relative velocities (it is also equation (6) in Mr. Woodbridge's thesis); while (1), the equation for *power* (work per unit of time), is founded on the principle of work and energy, and is assumed, without special proof, by Weisbach and Bresse.

Now it is a simple matter, by algebraic combination of some of these six equations, including (1), to deduce Rankine's expression for the power, as being equal to the difference in the *moment of the momentum* (of the mass of water flowing per unit of time) at entrance and exit, multiplied by the angular velocity. Hence, the establishment of Rankine's equation (call it equation (R); it is equation (8) in Mr. Woodbridge's article) by special proof is equivalent to the establishing of equation (1), and in our list of equations to be established, we may discard (1) and replace it by (R), if a student objects to (1) as obscure in principle. In such a case, therefore, it is important to prove (R) by as direct and convincing a method as possible, and such a method (by elementary volumes) is the one used by Mr. Woodbridge and the writer, not only for equation (R), but for (6).

Rankine's proof of equation (R) is very obscure to the beginner, and Prof. Unwin's, in the *Encyclopædia Brittanica*, though attempting to be more specific, seems extremely vague.

In the March number, 1880, of Van Nostrand's *Eng. Magazine*, may be found an article by the writer, in which the action of jets on vanes, and also the theory of the "turbine of free deviation" are investigated by the method of elementary volumes and their pressures. In the treatment of the former, attention is called to Rankine's neglect of a portion of the stream, as Mr. Woodbridge does in his recent paper; in treating the latter, the pressure of each element of the stream against the vane, at a given instant, is found, its moment about the wheel-axis formed, these moments summed, and this sum multiplied by the angular velocity ω to obtain the power exerted; the result of which (in equation (10) of that article) $= \omega \times$ change of "moment of the momentum" of the flow per unit of time; *i. e.*, this equation shows the truth of equation (R) for that particular case.

The form of proof of equation (R), prepared for the writer's classes, for any kind of turbine, will now be presented, consisting, as it does, of a consideration of the individual actions of all the

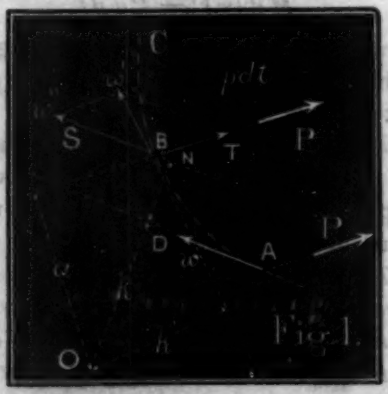
elementary vertical prisms into which we may divide the volume of water, which, at a given instant, occupies the wheel-channels.

Though following the same method (of elementary volumes) as that of Mr. Woodbridge, the present solution is, perhaps, less complicated, in that it does not require us to obtain a detailed expression for the pressure between each prism and the vane, while sacrificing nothing in rigidity of proof, nor in satisfactory minuteness of detail. It is convenient to divide it into three propositions:

PROP. I.—In any (outward- or inward-flow) turbine, if the pressures of the water against the vanes (or partitions between the channels) have reached a state of permanency, the wheel having a uniform angular velocity $= \omega$; then the work done by the water on the wheel per unit of time (or power) is

$$L = \omega \, \Sigma (P a) \qquad (a)$$

in which $\Sigma (P a)$ denotes the *sum of the moments, about the wheel axis, of all the elementary pressures of the water against the vanes at any definite instant.* (These pressures are, of course, normal to the surface of the vanes at their respective points of application. This proposition calls for no proof here, and we accordingly pass on to



PROP. II.—Let M be the mass of a small particle or "material point," *Fig.* 1, which, in describing a plane curve, A, B, C, under the action of one or more forces. Let $A\,B$ be any element of the path, described in a time, $d\,t$, while P is the resultant of all the forces acting on the particle at this point of the path. Call the velocity at A, w; that at B, w'; the acceleration due to P, call p.

Of course, $p = P \div M$. By the principle of the composition of motions, w' is the diagonal formed on w'' at B, parallel and equal to the w at A, as one side, and $p\,dt$ the increment of velocity due to the action of P during dt, as the other side of a parallelogram.

From any point, O, in the plane drop perpendiculars upon w'', $p\,dt$, and w'; also, upon the w at A. Denote the lengths of these perpendiculars by the symbols shown in the figure. Then the same geometrical relation will hold between w'' $(= w)$, w', and $p\,dt$, and their perpendiculars, as if ST were a parallelogram of forces. That is,

$$w'\,k' = w''\,(k + \overline{DN}) - (p\,dt)\,a$$

(The negative sign is due to the circumstances of this particular figure).

But as the distance $A\ B$ is considered shorter and shorter, $\overline{D\ N}$, ultimately vanishes as compared with the finite k; hence we may write, since

$$w'' = w \text{ and } p = P + M,$$

$$M\,(w\,k - w'\,k') = (P\,a)\,dt \qquad (b)$$

or, more strictly, with full calculus notation,

$$M\,d\,(w\,k) = P\,a\,dt \qquad (c)$$

That is, by multiplying the mass of the moving particles by the change which the product of its velocity by the perpendicular let fall upon the latter from any point, experiences in an element of time, dt, we obtain the product of dt by the moment of the resultant force about the same point. (As is well known, this principle can be used to prove Kepler's law that the radius vector of a planet sweeps over equal areas in equal times.)

PROP. III.—*The sum of the moments about the wheel axis of the pressures exerted by the water in the wheel passages against the vanes at a definite instant, is equal to the loss (or gain) of "moment of momentum," between entrance and exit of the mass of water flowing per unit of time* ("moment of momentum" being a name given by Rankine to the product of the mass of a particle × its absolute velocity, × perpendicular distance of this absolute velocity from the arbitrary centre of moments).

Conceive the water which at any instant lies in the turbine passages to be subdivided into a great number of vertical rings,

concentric with the wheel, of *equal volume* and of such small thickness that at the end of the time dt, each ring fills the exact space occupied by its neighbor at the beginning of dt. (See *Fig. 2.*) The dotted line $M N$ shows the absolute path, and initial and final absolute velocities, w_1 and w_0, of a particle, as the ring to which it belongs passes completely through the wheel. In the small time

Fig. 2.

dt, in which any one ring passes into its consecutive position, the portion A (of the ring) included between any two neighboring partitions (see *Fig. 3*,) passes into a position A' in the next ring-space, and in this new position, on account of the "state of permanency" of the flow, has an absolute velocity, w', equal to that, w'', which the portion B had at the beginning of the dt, while the

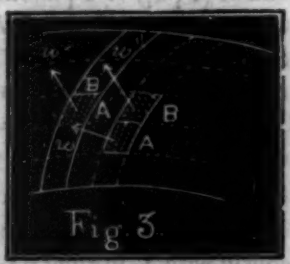


Fig. 3.

length of the perpendicular k', dropped on w' from the wheel axis, is the same in value as for B at the beginning of the dt, since the positions A' and B are in the same ring. In other words, the "moment" of the absolute velocity for A' (*i. e.*, the $w' k'$ of *Fig. 1*), about the wheel axis, at the end of dt, is the same in value as that for B, at the beginning of dt.

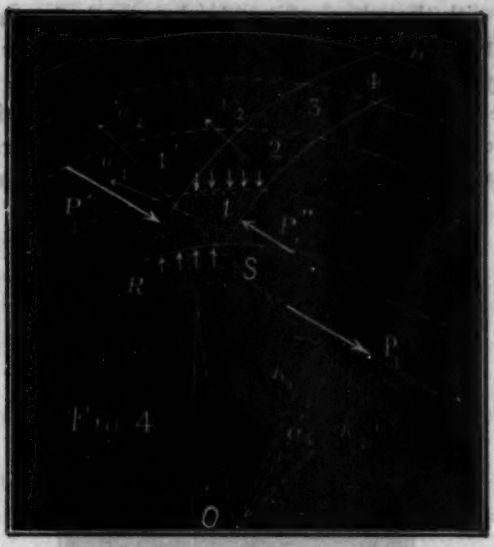


Fig. 4.

Now consider by itself (*i. e.*, as a "free body,") the prism 1, at the entrance of any one of the wheel channels, *Fig. 4*. P_1' and P_1'' are the pressures of the partitions against it; let P_1 represent their resultant; (it is, of course, the equal and opposite of the resultant pressure of this prism against the wheel at this instant). Since the pressures of the neighboring prisms against 1 have lines of action containing O the wheel axis, those pressures have no moments about O, and the moment $(P_1\, a_1)$ of P_1 about O is therefore equal to the moment about O of the resultant of P_1', P_1'', and the pressures on $L\,K$ and $R\,S$. During the time $d\,t$, prism 1 moves to position 1′ in the next ring-space, w_1 changes to w_2, k_1 to k_2. Hence, from Prop. II, equation (b) with $d\,M$ = mass of elementary prism, we have

$$d\,M\,(w_1\,k_1 - w_2\,k_2) = P_1\,a_1\,d\,t.$$

Similarly for the other prisms in this channel, between $R\,S$ and n, as they, simultaneously with 1, in time $d\,t$, move into their consecutive positions, we may write (remembering that all the $d\,M$'s are equal)

$$d\,M\,(w_2\,k_2 - w_3\,k_3) = P_2\,a_2\,d\,t$$

$$d\,M\,(w_3\,k_3 - w_4\,k_4) = P_3\,a_3\,d\,t$$

and so on, up to

$$d\,M\,(w_{n-1}\,k_{n-1} - w_n\,k_n) = P_n\,a_n\,d\,t.$$

Adding these equations, member to member, we obtain

$$\Sigma\,(P\,a) \text{ for one channel} = \frac{d\,M}{d\,t}\,(w_1\,k_1 - w_n\,k_n).$$

Hence, if the wheel has m channels

$$\Sigma\,(P\,a) \text{ for whole wheel} = \frac{m\,d\,M}{d\,t}\,(w_1\,k_1 - w_n\,k_n).$$

Now $m\,d\,M$ is the mass of water which leaves the wheel in time $d\,t$; hence, denoting by Q the volume of water passing per unit of time, and by γ the weight of a unit of volume, we have

$$m\,d\,M = \frac{Q\,\gamma}{g}\,d\,t$$

whence

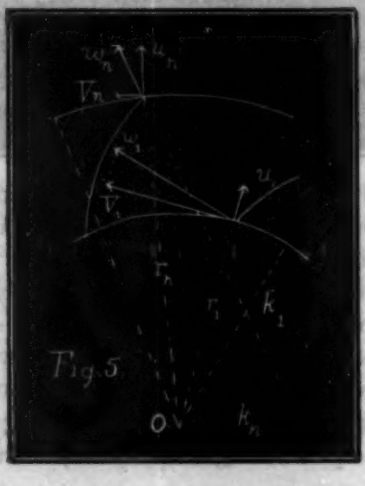
$$\Sigma\,(P\,a) = \frac{Q\,\gamma}{g}\,[w_1\,k_1 - w_n\,k_n] \qquad (d)$$

= the total moment with which the water acts on the wheel, as some would express it.

Finally, therefore, substituting from equation (a), we have the power of the wheel

$$L = \omega\,\Sigma\,(P\,a) = \omega\,\frac{Q\,\gamma}{g}\,[w_1\,k_1 - w_n\,k_n] \qquad (e)$$

which is equation (*R*), whose truth it was required to establish by a consideration of elementary volumes and pressures.



If, following Rankine's form of expression, we resolve the absolute velocities w_1 and w_n, of entrance and exit, of the water particles into components radial and tangential to the two circumferences of entrance, and exit, we may also write (from similar triangles)

$$L = \omega \frac{Q\gamma}{g}\left[V_1 r_1 - V_n r_n\right] \qquad \text{or } \overset{(f)}{(R)}$$

Fig. 6.

in which V_1 and V_n are the initial and final "velocities of whirl" as Rankine calls them, and r_1 and r_n the corresponding wheel radii. (This is Mr. Woodbridge's equation (8)).

We now pass to the proof of the equation referred to as (6) [both in Mr. Woodbridge's article and in that of the writer in JOURNAL FRANKLIN INSTITUTE, May, 1884.] showing the relation between the relative velocities and the pressures at entrance and at exit (Bernoulli's theorem for a uniformly rotating horizontal pipe or channel, as the equation might be called). The closely related

problem of the frictionless motion of a small solid or particle in a pipe of any form (of single curvature) rotating with a uniform angular velocity in a horizontal plane about a fixed axis (vertical, of course,) may be treated at the same time with but little extra detail, and is accordingly presented, being solved by a method of the writer's, not heretofore published in any periodical, but according to his experience, of a very direct nature in satisfying the student mind. In *Fig. 6*, $O\,B'$ is the absolute path described by the particle in a time $d\,t$; *i. e.*, in time $d\,t$ the pipe has rotated through an angle $\omega\,d\,t$, carrying O to O', and the particle itself, having at this instant a relative velocity $= v$ along the pipe, has described a distance $= v\,d\,t$, $= \overline{O\,B}$, $= \overline{O'\,B'}$, along the pipe. Let $\rho =$ the radius of curvature of the guide at this point, while r the radial distance of O and O' from the axis C is the radius of the circular arc $O\,O'$. The absolute velocity w, of the particle, is the diagonal formed on $\omega\,r$ and v, and by the principle of the composition of motions the absolute motion $O\,B'$ may be considered to result from the simultaneous compounding (by parallelograms) of the following component motions, viz.:

(*To be continued.*)

A NEW METHOD TO DETERMINE THE MOON'S MASS CORRECTLY, FOLLOWED BY A DISCUSSION UPON THE THEORY OF TIDES FULLY IDENTIFYING THE PHENOMENON UPON DYNAMICAL PRINCIPLES.

BY L. D'AURIA.

[*Presented in a Lecture delivered before the* FRANKLIN INSTITUTE, *Friday, February 25, 1887.*]

Let $M =$ mass of the earth;

$\mu =$ mass of the moon;

$D =$ distance between their respective centres;

$\omega =$ angular velocity around their common centre of gravity;

$x =$ distance between this centre of gravity and that of the earth;

$\rho =$ radius of the earth at a latitude whose *sine* $= \frac{1}{\sqrt{3}}$;

g = acceleration of gravity at such latitude;

$m = \frac{1}{g}$ = unit of mass;

c = constant of attraction.

Then we have

$$\frac{c\ M\ \mu}{D^2} = M\,\omega^2\,x;\quad M\,x = \mu\,(D - x).$$

Eliminating x, and solving for c, we find

$$c = \frac{D^3\,\omega^2}{M + \mu}$$

At a latitude whose *sine* $= \frac{1}{\sqrt{3}}$ the centre of attraction is found to coincide with the centre of figure of the earth (Laplace, *Mécanique Céleste*); therefore we can write

$$\frac{c\ M\ m}{\rho^2} = \frac{c\ M}{g\ \rho^2} = 1$$

from which

$$c = \frac{\rho^2 g}{M}$$

Comparing the above two expressions of c, we obtain the equation

$$\frac{\rho^2 g}{M} = \frac{D^3\,\omega^2}{M + \mu}$$

which gives

$$\frac{M}{\mu} = \frac{\rho^2\,g}{D^3\omega^2 - \rho^2 g} \qquad (1)$$

In this expression, ρ and g are constant, and their values are determined with all desirable accuracy. The term $D^3\,\omega^2$ should also be constant, since the ratio $\frac{M}{\mu}$ is a constant number under all circumstances. But taking into account the sun's disturbing force, we find that our fundamental equations can only be verified simultaneously when the earth and moon are in quadrature; for only then the common centre of gravity of the earth and moon coincides with the centre of gravity of such system with reference to the sun's attraction. Hence, in equation (1), we shall always mean for D and ω the values which correspond to the quadratures, and

which should be ascertained by a series of observations directed for such purpose.

However, if we take the mean values of D and ω and form the product $D^3\,\omega^2$, this cannot differ but little from the proper one, and in all probabilities the difference will not affect significantly the value of μ. In such case, if we put $D = n\,a$, in which a is the equatorial semi-diameter of the earth, we have

$$\frac{M}{\mu} = \frac{\rho^2 g}{n^3 a^3 \omega^2 - \rho^2 g} \qquad (2)$$

This expression can be very much simplified by finding the value of ρ in function of a. To this effect, if we denote by θ the latitude whose *sine* $= \frac{1}{\sqrt{3}}$, we have

$$a^2 y^2 + b^2 x^2 = a^2 b^2;$$

$$y^2 = \rho^2 \sin^2\theta;\ x^2 = \rho^2 (1 - \sin^2\theta).$$

Hence

$$(a^2 \rho^2 - b^2 \rho^2) \sin^2\theta + b^2 \rho^2 = a^2 b^2.$$

Substituting $\sin\theta = \frac{1}{\sqrt{3}}$, we find

$$\rho^2 = \frac{3\,a^2 b^2}{2\,b^2 + a^2}$$

Putting $\frac{a-b}{a} = \varepsilon = \frac{1}{298}$, and eliminating b, will be found after reductions

$$\rho^2 = \frac{a^2}{1{\cdot}00225}$$

Substituting in equation (2), we get

$$\frac{M}{\mu} = \frac{g}{1{\cdot}00225\,\omega^2 n^3 a - g}$$

Using the following data:

$a = 20{,}923{,}990$ feet (Clarke's mean value);

$g = 32{\cdot}18169$ "

$n = 60{\cdot}273433$ " (Herschel's tables);

$$\omega = \frac{2\pi}{60 \times 39343{\cdot}183};$$

and assuming $M = 1$, will be found

$$\mu = \frac{1}{91{\cdot}75}$$

The value of μ adopted in Herschel's tables of lunar elements is $\frac{1}{88}$, which differs about three per cent. from our value. But it must be remembered that, since Laplace's first determination of the moon's mass, μ has been through the following series of values

$$\frac{1}{75}, \frac{1}{80}, \frac{1}{83}, \frac{1}{88},$$

showing how uncertain the methods hitherto employed are. In fact, with these methods, the mass of the moon is deduced from the effect its attraction produces upon the equatorial protuberance of the earth, which causes the nutation of the earth's axis; and also from the effect such attraction causes upon the waters of the oceans in proportion to that occasioned by the sun's attraction. Both these methods imply uncertain data, and involve the most abstruse resources known to astronomical science.

It may be that using the proper value for $D^2\,\omega^2$ in our equation (1), μ will be somewhat modified; but, unless the value of n given in Herschel's tables is not very accurate, we are inclined to think that the correction of μ would be very slight.

[In a letter elicited from Prof. Newcomb, of the Washington *Nautical Almanac*, we are informed, that, using the latest value of the moon's parallax, as determined by observation; that is, correcting n according to such value, our equation (1) would offer

$$\mu = \frac{1}{83{\cdot}4}.$$

By the observed constant of nutation and the observed value of the lunar equation in the motion of the earth around the sun, the same authority informs us that it has been found approximately

$$\mu = \frac{1}{81}.$$

It would seem that the value of n, given in Herschel's tables, is not sufficiently exact.]

(*To be continued.*)

BOOK NOTICES.

ELEMENTS OF GEODESY, for the use of students. By Prof. J. Howard Gore; Columbian University. New York: John Wiley & Sons. 1886.

We have just finished reading this interesting octavo volume of some 250 pages, well written and excellently printed. All who have given attention to the subject treated, will certainly feel gratified that a work of this description, so clear and concise, has issued from the American press. We may divide the treatise into two distinct parts, The first 100 pages may be said to be descriptive of the apparatus and processes relating to the art; and the remainder of the work treats of the methods of calculation, or of the mathematics involved. The latter has received the attention of many eminent mathematicians, but the student will find here their labors arranged for practice, with thorough knowledge of the subject. We can hardly praise this portion of the author's volume too much, nor commend too highly the typography; everything is as it should be. With regard to the descriptive portion, however, we have some criticisms to offer. Valuable information is certainly contained in it, yet more might have been added. The main apparatus of geodesy; that is, the measuring rods for bases and the transit for determining angles, are not explained and illustrated with the completeness necessary to initiate a student into the art. Although the work is professedly written for beginners, yet it is better adapted to practitioners as a hand-book, from lack of such full descriptions. In all good technical schools, the mathematics of geodesy may be taught by any professor of this branch of learning, but few such schools are provided with base rods and large transits to exhibit to students. Hence the need of full descriptions of them. Again, the self-taught student, who is often distant from the libraries of large centres of population, where alone additional works on geodesy are procurable, will not rest satisfied with the meagre remarks given in this treatise.

The author mentions merely the various kinds of base rods that have been used in different countries, and seems to consider, (contrary to our opinion,) the coast survey arrangement as the best one, which he explains more in detail than any other. We object to every measuring apparatus, whether for lines or angles, that consists of many parts, that is burdened with levers, screws, verniers, micrometers and microscopes. We object, especially, to movable parts. To resume, the author, in our opinion, should have added plates to his work, where every base apparatus mentioned by him should have been drawn to scale in a complete manner, so that they might have been reproduced, if necessary, in a workshop.

Opposite p. 35, is given a fine illustration of what seems to be the latest form of coast-survey transit. Now, we maintain that cross-sections also of the instrument should have appeared on additional plates, in order that its mechanism might become evident to a student. Critical remarks in regard to it might also have been added; for instance, the reasons given for the

introduction of the U-support to the telescope; for the use of three levelling-screws in place of four; for the conical shape of the limb, or graduated circle; for the use of a level on the latter; for the vertical clamp of the telescope; for the position of the horizontal clamp half-way between the microscopes; for the micrometer in the focus of the telescope, etc. Prof. Gore is apparently an advocate of the micrometer screw in opposition to the vernier, like most American and English geodesists. But we incline, with Continental practitioners in Europe, to the vernier, which we believe is virtually a superior arrangement for *field* instruments. The question is, really, not one between verniers and micrometer screws, but of accurate work in the *mechanism* and graduation of the instrument. What avails a fine reading of an angle when the metal of the instrument is not uniform in density and quality; when the graduation is too imperfect, the eccentricity too variable, the spindles and axes incorrectly made, and when the clamping screws press directly, with a rotary motion, on the axes and graduated plate? Lost or irregular motion in the spindles and telescope axes is the capital point; and to secure good work, we advocate that the construction of these portions of an instrument should be made a specialty by some manufacturer, provided with elaborate machinery for the purpose. The genius of our people for mechanism should overcome this difficulty.

In conclusion, we would respectfully suggest to the author that, in a second edition of his work, he will treat, with the completeness which the subject demands, the descriptive portion relating to field apparatus, and then we shall assuredly have a model work on geodesy. E.

OBLIQUE ARCHES. By John L. Culley. BEAMS AND GIRDERS. By P. H. Philbrick. New York: D. Van Nostrand. 1886.

We have received Nos. 87 and 88 of Van Nostrand's Science Series, on "Oblique Arches," by John L. Culley, and on "Beams and Girders," by P. H. Philbrick. Both of these small works are elementary in character, and well suited to introduce their respective subjects to beginners. Their small, compact form render them very portable, and their low price, accessible to all. Much, indeed, may be learned from them. E.

SCIENTIFIC NOTES AND COMMENTS.

ASTRONOMY AND PHYSICS.

RELATION BETWEEN CERTAIN SOLAR PHENOMENA AND VARIATIONS IN TERRESTRIAL MAGNETISM.—M. E. Marchand (*Comptes Rendus*, **104**, 133) details results of comparisons of variations of the magnetic elements (as observed at Lyon) with the position of spots and faculæ on the solar disc. Regarding the sum of the variations of the three magnetic elements reduced to the same unit, as the measure of the intensity of the disturbance, a suitable curve represents the changes of intensity of disturbance. Comparing this with the passage of spots and faculæ over the solar disc, he concludes that each maximum intensity of disturbance sensibly coincides with the passage of a group of spots or of a group of faculæ, by the point of its shortest distance from the centre of the solar disc. There seems to be no relation of amount of disturbance with diameter of the spots. There are, however, at times on the solar surface well marked regions of activity, whose passage over the central solar meridian, at successive rotations, is accompanied by magnetic disturbances quite as marked. Simple inspection of the curves of the recording instruments reveals the fact that great disturbances are separated by an interval sensibly equal to, or a multiple of, the apparent rotation of the sun.

M. B. S.

HARVARD COLLEGE OBSERVATORY.—(*Boyden Fund*).—By the will of the late Uriah A. Boyden, property, the present value of which exceeds $230,000, was left in trust for the purpose of astronomical research "at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences."

The Trustees of this Fund have transferred the property to the President and Fellows of Harvard College, in order that the researches proposed by Mr. Boyden may be directed at the Harvard College Observatory. These researches will be supported by a portion of the means of the Observatory, in addition to the trust fund itself.

In order that the intentions of the donor may be successfully executed, it will first be necessary to obtain all practicable information with regard to the altitude, accessibility and climate of various mountainous regions which might naturally be selected as suitable places for the proposed observations. It will apparently be desirable that the work done at any selected station should be almost exclusively confined to that of observation, the records of which can be reduced and discussed to better advantage at the Observatory of Harvard College. For preliminary experiments one or more stations are required, at such altitudes that they will show what advantages are to be expected when the effect of the air is diminished. For the permanent station to be eventually occupied, it is probable that a very great altitude will be advisable. Ease of access is important, to permit the necessary instruments

and supplies to be transported. The climate must be such that the station can be occupied at all seasons of the year. A location in the southern hemisphere will be preferable for various reasons. The southern stars invisible in Europe and the United States have been less observed than the northern stars, and by the aid of a southern station the investigations undertaken at Cambridge can be extended upon a uniform system to all parts of the sky.

The Observatory of Harvard College accordingly desires to obtain all the information which can be of value, in view of the foregoing requirements, to enable a suitable station to be selected. It is hoped that some of the published and unpublished sources of such information may be sent as gifts to the Observatory. When this is not practicable, any information will be welcome which may lead to the purchase of such material. Records of meteorological observations made at considerable altitudes, books of travel giving full descriptions of mountainous regions, guide books and photographs of such places, will all be of much value for the purposes above mentioned.

Detailed information is also desired on the following subjects relating to any places which appear to fulfil the conditions of the trust.

(1.) Latitude and longitude. Distance and direction from some town, or other well known point. Height, and how determined.

(2.) Peak, pass, or table-land. Character of surface, ledge, broken rock, gravel, or covered with trees, shrubs, or grass. Prevalence of snow in summer, and period during which the depth of snow in winter might obstruct the paths of access, or occasion other inconvenience or damage. Proximity of wood for fuel, and of water.

(3.) Means of access, distance from and height above the nearest railroad station, wagon road, bridle path, or foot path. Time of ascent and descent. Nearest post-office and telegraph station, and their distances from the proposed station. Nearest point of road kept open in winter.

(4.) Observation of the rainfall at different seasons of the year. Proportion of the sky covered with clouds at different hours and seasons. These observations are desired at sunset, sunrise, and late in the evening. Such observations may also be made of a distant mountain peak, confining the evening observations to moonlight nights. Observations of the barometer and thermometer are also desired. Information is wanted regarding the prevalence of very high winds; the presence of dust, haze, or the smoke from forest fires, rendering distant points invisible; and all other meteorological phenomena affecting the value of the station for astronomical purposes. If there is a rainy or cloudy season, its duration; also the regular recurrence of clouds, thunder storms, or wind, at any given hour of the day.

(5.) Sketches or photographs of the proposed location, and of points on the road; also of the view.

Correspondence is invited with those residing near or in sight of suitable locations who are willing to undertake any of the observations described above, and also with any persons who have information of any kind likely to be useful in accomplishing the purposes of the trust established by Mr. Boyden.

EDWARD C. PICKERING,
Director of Harvard College Observatory.

Cambridge, Mass., U. S. A., March 1, 1887.

DISTURBANCE OF ASTRONOMICAL LEVELS BY AN EARTHQUAKE.—Th. Albrecht (*Astron. Nachr.*, **116**, 130,) details the observation of remarkable disturbances in the levels during the Berlin-Breslau-Königsberg longitude determination, and as doubtless due to an earthquake wave. Individual observations of this character had been frequently made, but it had not hitherto happened that at three stations simultaneous observations should be made, which allowed *inter se* quantitative comparison.

On the morning of September 20, 1867, Wagner, of the Pulkova Observatory, had found the level of the transit instrument in such violent oscillation that no reading could be made; the greatest amplitude being 3″. An earthquake had taken place in Malta less than thirteen minutes previous, and the wave had consequently required that time to pass over an arc of 26° on a great circle. Among a number of other cases cited an observation made by Nyrén, at the Pulkova Observatory, May 10, 1877, is noteworthy; the disturbance having been traced to an earthquake at a point on the west coast of South America, Iquique, distant 112°·6 on a great circle from Pulkova, where the wave arrived one hour, fourteen minutes after the main shock had occurred.

The level disturbances here referred to occurred on the evening of August 2, 1885, and were simultaneously observed by Albrecht in Berlin, Richter in Breslau, and Borrass in Königsberg, and were, respectively, 2″, 4″ and 7″ in amplitude, and lasted about fifteen minutes at each station. The beginning of the disturbance could more accurately be got from the Berlin observations, and was set down as ten hours thirty-nine minutes Berlin M. T. A few days later, it was learned that a severe earthquake had occurred in Turkestan during the night of the 2d to 3d of August, the centre of disturbance being in North Latitude 42° 40′, East Longitude 74° 45′. In the city of Pischpek (Latitude 42° 50′, Longitude 74° 39′ East), the first and most severe shock occurred at ten hours, fifteen minutes Berlin M. T. The disturbance of the level at Berlin consequently began about twenty-four minutes later. Berlin being distant on a great circle from the earthquake centre 41°·1, the velocity of the wave is consequently 3·2 kilometres per second. As this value and that derived from the other cases here mentioned, is greater than that derived from ordinary seismological observations, these disturbances may have been due to the great depth of the centre of action. Particularly do these observations point to the desirability of constructing appliances for registering the condition of sensitive levels, as important means of furthering knowledge of the internal structure of the earth. M. B. S.

PERIODIC VARIATIONS OF THE SPOTS OF JUPITER.—M. Lamey (*Comptes Rendus*, **104**, 5,) contributes some interesting results concerning the periodicity of the markings of Jupiter. M. Niesten, of the Brussels Observatory, had, from the great red spot of recent years, derived a period of variation of about six or seven years. M. Lamey, however, from a series of 583 drawings of this planet, covering a space of six years, concludes a periodic variation of about five and one-half years. As in the case of sun spots, the bands of Jupiter are subject to the same law of distribution in latitude.

These bands—ordinarily two in number—are to be found near the equator and near each other at an epoch which seems to precede the maximum of activity. Then follows a separation, and the formation of numerous secondary bands, until the motion of the bands in latitude leads to their disintegration, and, particularly in the northern hemisphere, to an absence at times of almost all markings. The period in its oscillation about a mean, is expressed in years as $5\cdot43 \pm 0\cdot07$, just as in the case of the sun we have $11\cdot11 \pm 0\cdot287$. The last equatorial concentration appears to have attained its maximum the twenty-third of March, 1885. M. B. S.

STELLAR PARALLAX DETERMINED BY PHOTOGRAPHY.—Rev. Prof. Pritchard (*M. N. Royal Astron. Soc.*, **47**, 87,) presents the results of some photographic experiments made at the University Observatory, Oxford, with the view of determining the parallax of 61^1 *Cygni* and 61^2 *Cygni*. This star was, of course, selected on account of the numerous determinations of its parallax since the noted measurements of Bessel; thus affording an excellent test of the new method. Four faint neighboring stars were selected for comparison, and the distances of these measured from each of the components of 61 *Cygni*, on some 200 plates, taken on fifty nights. The mean results, which, as yet, must be regarded as provisional only, are for 61^1 *Cygni*, parallax $0''\cdot438$; for 61^2, parallax $0''\cdot441$. The value of the parallax of 61 *Cygni* is, as determined by Bessel, $0''\cdot348$; Auwers, $0''\cdot564$; Ball, $0''\cdot468$; Asaph Hall, $0''\cdot478$. M. B. S.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, March 16, 1887.*]

HALL OF THE INSTITUTE, March 16, 1887.

MR. JOSEPH M. WILSON, President, in the Chair.

Present, 194 members and 41 visitors.

Additions to membership since last meeting, eleven.

On behalf of the Special Committee on "State Weather Service," the Chairman, MR. W. P. TATHAM, made an oral report of progress.

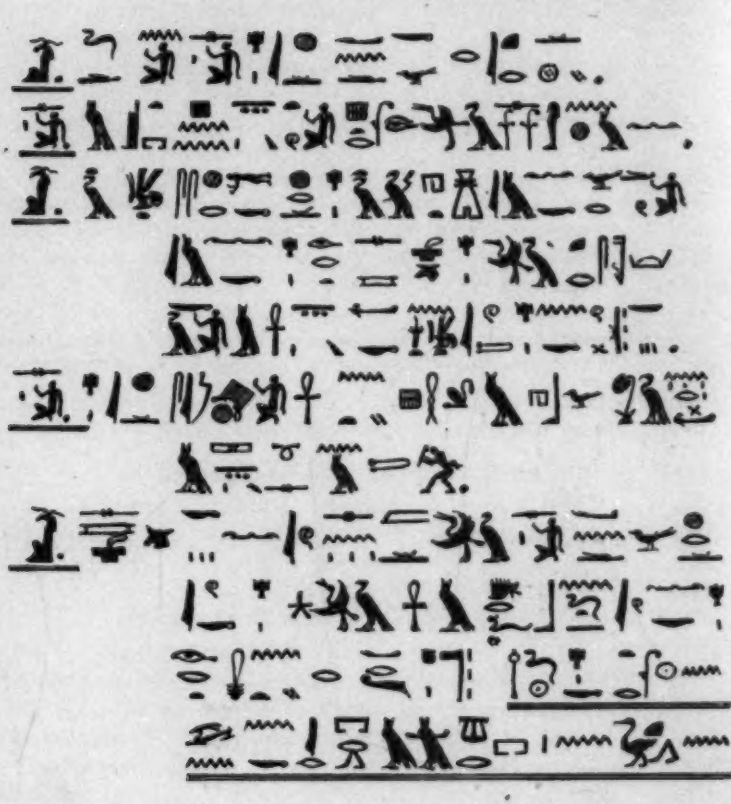
The Secretary made a similar report on behalf of the La Cour-Delany Committee.

MR. GEORGE S. STRONG, of New York, read a paper on the "Strong Locomotive." The paper, with discussion thereon, has been referred for publication.

PROF. ELIHU THOMSON, of Lynn, Mass., read a paper on "Electric Welding," illustrating the same by the exhibition of a large collection of specimens, demonstrating the wide range of application of the new art. The paper, with discussion thereon, has been referred for publication.

The meeting thereupon proceeded to the consideration of certain propositions of the Committee on Reorganization for the Amendment of the By-Laws. Adjourned.

WM. H. WAHL, *Secretary*.



THE GOD CREATOR **KNUM** AND A MODERN PESSIMIST.

I. KNUM.—Tell me, oh Pessimist, why art thou so sad?

II. PESSIMIST.—It is because down here I only see around me the formidable image of nothingness.

III. KNUM.—The coffin terrifies, I know, but what is the use of always fastening thy gaze on the tomb?

IV. What is the use of eternally philosophizing on the sepulchre?

V. Sovereign of everything, thy power stretches over the whole universe.

VI. PESSIMIST.—What! Glorify that melancholy existence which is miserably extinguished in a supreme mourning!

VII. Venerate a life that death will soon envelop in shadow!

VIII. KNUM.—Thine arguments are not logical, oh! Pessimist!

IX. It is just because it is not durable that life ought to be loved with adoration.

X. Conform thyself rather to the beautiful maxim of the divine book, which says[1] "*Rejoice greatly whilst thou art in life, for*"

XI. "*The solemn tomb does not give back its prey.*"

---

[1] The quotation underscored is from the *Papyrus Prisse*, pl. XIV, 1, 12, 3; one of the most ancient papyri we possess. Its composition, if not its handwriting, belongs doubtless to the first dynasties of the Old Empire.